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24	This book represents a popular explanation of the basic questions concerning	
26	the technology of rockets. The principles, workings and applications of rocket	
28	power and rockets, and also the history, present state, future progress, and the	
30	role of native scientific-technical ideas in rocket construction are all explained	
32	in detail. This book is planned for a wide range of readers.	
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INTRODUCTION

Rocket technology is one of the most interesting and promising branches of contemporary technologies. Progress in rocket technology and jet aviation during recent years has led to significant increases in speed and altitude of aircraft, and opened prospects for the creation of high-speed aerial transportation and the future realization of flights into space. Ascents of altitude rockets made new data available on the composition and characteristics of the upper layers of the atmosphere.

World War II was the start of extensive use of rocket weapons in technical warfare. Developments went back to long before the war. Already with the perfection of the well-known earlier gunpowder rocket engine, great attention was given to the development of a new type rocket engine - one powered by liquid fuel. In this development considerable technical difficulties in design and use of the new heat engine had to be overcome. Before being able to design an engine suitable for aircraft use an entire series of complex problems had to be solved and prolonged and painstaking experimental work was necessary. This work is continuing at present.

During the war many models of both gunpowder and liquid-fuel rocket engines and rockets for various purposes were developed and tested. The first rockets built possessed enormous speeds, altitude, and range compared to the usual missiles. Rockets were used in various branches of the army. Guided rocket missiles were developed under combat conditions, designed for destruction of close-range as well as distant aerial, land and naval targets. This trend in combat rocket technology in postwar years produced considerable progress. The foreign press reported newer and newer models of guided missiles for the army, air force, and navy. For their development and testing they built and are presently building numerous research centers and proving grounds extending hundreds and thousands of

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0 kilometers. Thousands of engineers and technicians are occupied in the completion
 2 of a vast program of research, whose goal is the improvement of rocket missiles.
 4 For conducting this work enormous sums are allotted in the budgets of imperialistic
 6 governments.

8 The development of guided missiles and rockets is impossible without using the
 10 achievements of a whole series of branches of science and technology, including
 12 such new fields of science as radio-location, electronics, automation and tele-
 14 mechanics; it has a bearing on the entire practice of present-day industrial pro-
 16 duction.

18 During the last few years the building and testing of altitude rockets, intend-
 20 ed for ascents to the higher layers of the atmosphere, together with the work on
 22 guided missiles for military purposes have been prominent in research work. These
 24 ascents, many of which have been made to date, provide valuable information which
 26 is indispensable to meteorology, geophysics, astronomy, and likewise to aviation
 28 and artillery. Numerous publications mention the creation of a man-made earth,
 30 satellite which could be used for research purposes.

32 Russian-trained engineers and inventors made the greatest contribution to the
 34 progress of rocket technology.

36 The famous scientist Constantine Eduardovich Tsiolkovsky developed the theory
 38 of rocket flight, the basis of rocket technology and jet aviation, and created the
 40 science of interplanetary travel.

42 The history of rocket technology contains the names of the creators of the
 44 Russian combat rocket A.D.Zasyadko, E.E.Konstantinova, N.E.Kibalchich, author of
 46 the first project of gunpowder rocket aircraft, F.A.Tsander, U.V.Kondratyuk and
 48 other Soviet-trained engineers and researchers, working on the theory of jet pro-
 50 pulsion, construction of engines and rockets powered by liquid-fuel, and likewise
 52 those engaged in investigations on the theory of interplanetary travel.

54 The workers in Soviet rocket technology were worthy followers of the famed
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0 tradition of the founders of domestic rocket design.

2 The combat rocket with smokeless powder was created in the Soviet Union, mark-
4 a new rise in rocket armament technique. In the battles of our great Fatherland
6 war this new weapon earned the unfading glory of Soviet rocket armaments. The
8 Soviet Union was the first to develop basic design principles for the liquid-fuel
10 rocket whose progress lifted rocket technology to a new higher level. Back in the
12 Thirties the first successful flights of Soviet rockets were made.

14 Relentlessly fighting for peace throughout the whole world, the Communist
16 party and the Soviet government strengthen the active defense of our Native Land
18 against encroachments by her enemies. We have all that is necessary to deliver a
20 crushing blow to the enemy should he dare resort to aggression.

22 The appearance of atomic weapons, pilot-less guided rocket missiles capable of
24 carrying atomic bombs over great distances, gives important significance to the
26 nations of the aggressive block.

28 The imperialists strive to convert the rocket to a monstrous weapon of destruc-
30 tion. However, progressive mankind, which rose to struggle for peace against war-
32 mongers, will not allow this.

34 Increasingly wider applications are found for rocket engines in aviation,
36 where they open prospective fields of use for extremely high-speed flying. Pro-
38 jects and experimental designs for supersonic rocket aircraft are already known.
40 Experimental flights at supersonic speed are being carried on. Data are accumulat-
42 ing which will help designers and technologists to create high-speed machines.

44 Through the medium of scientific and technical progress, rocket technology,
46 as the rest of new techniques (radio location, atomic energy and others) serves us
48 and will continue to serve in the guarding of peaceful constructive labor, and the
50 development of national economy and culture. The efforts of our science and tesh-
52 nology are directed toward peaceful construction and further prosperity of our
54 Fatherland. The rocket - a weapon of war in the hands of the imperialists -

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0 becomes in our hands a new instrument of science, uncovering secrets of nature, and
2 a means of transportation and communication before which lies a brighter future.

4 The rocket will gain a secure position in the economy of the nation and will
6 help to verify and supplement our present knowledge of atmosphere. Rockets carry
8 aloft automatic devices to enormous heights to uncover the enigmas of the aerial
10 ocean. It will become possible to build a man-made satellite, a laboratory for
12 investigation beyond the atmosphere, permitting important scientific observations
14 under conditions unattainable on Earth.

16 Meteorological rockets will fly to altitudes not reachable by sounding balloons
18 with instruments. Spanning enormous distances at high speeds, such a rocket will be
20 able to photograph the weather over large areas, transmitting by radio information
22 on the condition of the atmosphere at different altitudes of various regions.

24 After the missiles, man will penetrate the atmosphere in rockets. The time
26 will come when the Soviet citizen will have facilities at his disposal to fly from
28 one end of the Fatherland to the other in only a few hours. Rockets will carry
30 mail, freight, and passengers at great altitudes and at speeds not yet attained
32 even by extreme-range missiles.

34 When atomic engines are practicable, the potentialities of rocket technology
36 and aviation will grow immeasurably. Fulfillment of the sacred dream of mankind of
38 realizing interplanetary communication is approaching. The president of the Academy
40 of Science of the U.S.S.R., A.N. Nesmeyanov, said: "Science has reached such a level
42 that a stratospheric flight to the Moon is tangible, including creation of an arti-
44 ficial earth satellite."

46 As new techniques enter our life, the time will come when we will be as
48 accustomed to rockets and rocket aircraft as we are now accustomed to propeller
50 aircraft, radio, and electricity.

52 "Stories About Rockets" is written for readers who are interested in new
54 rocket techniques and desire to become acquainted with its principles.

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FIRST STORY

WHAT IS A ROCKET?

1. A Weapon of War and a Weapon of Science

"At the beginning of the 14th century, black powder was borrowed from the Arabs by the Western-European people and, as it is known to every child of school age, it brought about a complete revolution in the entire military science".

This was written by F. Engels (Bibl. 1). The revolution created in military sciences by black powder resulted in the birth of a new weapon - the rocket.

The rocket did not immediately conquer its place in the military field. Before the 19th century, only separate, unconnected information on rockets was given in literature. Later, the rocket underwent violent development in a century of progress, recognition, success and finally gradual decline. At the end of the last century, all surpluses of the rocket artillery in armies were eliminated.

The 20th century is a new period of development of the rocket. The intensive development of rockets started after the First World War. Less than half a century later, a new threatening weapon appeared on the battle fields of the Second World War. Various rocket weapons, rocket projectiles of various types and designations were developed and applied by the armies.

The first rocket fighter-airplanes appeared during the war.

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Reaction airplanes which could develop speeds of 1000 km per hour or more have found an extensive use in aviation. Aviation rocket engines have opened a possibility of realizing experimental flights at supersonic speeds. With their help it can be made possible to reach tremendous altitudes and speeds of several thousand kilometers per hour.

The development of rocket techniques during recent years has brought us closer to the practical realization of mastering cosmic speeds and interplanetary travels. Interplanetary travel is the task for the near future. Such is the progress and perspectives of modern rocketry.

Two principal fields of rocket activity are aviation and artillery. Each of these fields has its own peculiarities.

An artillery rocket has a motor for a single action, the thrust of which can be regulated by pre-defined laws.

Aviation rocket engines are intended for multiple use and the produced jet can be extensively used by the pilot. The rocket contributed many new achievements to aviation and to artillery. Low cost, simple construction, and light weight of starting devices, the absence of recoil have helped it to become a weapon for airplanes, tanks, and light landing boats.

Field rockets, antitank rockets, antiaircraft rockets, tank rockets, long range rockets, rocket torpedoes for naval and aviation use were used by infantry and tank divisions, by antiaircraft defense and in aviation, by navy and long range artillery.

Rocket projectiles and mines, rockets and rocket-torpedoes for close and long range were a surprise for many targets: for infantry, tank troupes, airplanes, ships, and for cities.

Demolition and fragmentation rockets, flares and incendiary projectiles, rockets with stabilizers and spin, winged and wingless rockets, single and multi-rockets constitute the arsenal of rocket artillery.

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0 The use of rocket torpedoes in the Air Force and in the Navy are the newest
2 developments in warfare introduced during the time of the last war. Rockets were
4 employed in aviation not only as a weapon. Starting rockets were employed as boost-
6 ers at the take-offs of aircraft, aerial torpedoes, and certain types of guided
8 missiles were developed.

10 The rocket technique was applied to scientific research. Until recently re-
12 search of the highest strata of the atmosphere was conducted only by indirect
14 methods, i.e., by observation of various phenomena from the ground. A rocket is
16 able to carry instruments to altitudes otherwise inaccessible by any other means.

18 High velocity flying mechanisms powered by rockets are used for high-speed
20 analysis in aerodynamics.

22 In altitude and range, the super-long range artillery projectiles were sur-
24 passed by the long-range rockets, which latter do not require any special launching
26 devices. The rocket-boosters proved their usefulness in aviation by reducing the
28 taxing time of an airplane to approximately one-half. Rocket-airplanes became a
30 step toward the new era previously mentioned by Tsiolkovskiy, the era of jet and
32 stratoplanes.

34 Rockets flying at supersonic speeds and climbing to tremendous altitudes are
36 not only of long range, but they are the investigators of high altitudes, the
38 stratosphere.

40 In the future they will be used for transportation beyond the atmosphere as
42 interplanetary ships, capable of overcoming the force of gravity. They will be
44 the ships of the future.

46 The military technique, transport aviation research and conquering of the
48 aerial ocean, interplanetary flights are the fields where the rocket is or will be
50 of great importance.

52 It will be invaluable in Meteorology and Astronomy, Geophysics and Aerodynam-
54 ics and it will help men to solve the riddles of nature.

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0 The progress in rocketry requires efforts and cooperation of many fields of
2 technological and technical sciences as: metallurgy, chemistry, instrumental in-
4 dustry, mathematics, aerodynamics, radar operation and others; it demands the
6 realization of industrial experience.

8 At the present time, in all technically-advanced countries of the world, a
10 great attention is directed to the investigations connected with the development and
12 employment of rocket engines and rockets. Rocketry is one of the most modern
14 branches of modern technology, it is progressing at high tempo.

18 2. The Reaction Force

20 A firework rocket and a rocket projectile, a rocket airplane and stratospheric
22 rockets are constructed differently and differently intended. But they all have
24 something in common that makes them different from a conventional airplane and an
26 artillery projectile, and also relates them; they are propelled by a reaction
28 force, the thrust.

30 The study of a simple powder rocket which is shown in Fig.1 will help us to
32 understand why a rocket projectile moves and why a rocket airplane flies.

34 The rocket has a powder charge. While burning, the powder is converted into
36 gases. The gases push in all directions with a tremendous force, capable of tear-
38 ing the rocket into pieces. However, it does not occur because the gases have a
40 free outcome.

42 The gas stream flows out at a high velocity and creates reaction force,
44 which moves the rocket.

46 Why does reaction force occur?

48 One of the laws of mechanics states that the reaction of two bodies upon each
50 other are equal and contrarily directed.

52 Looking carefully around us, we can observe the manifestation of this law
54 everywhere. We shall find this rigid law functioning both in nature and in

mechanics.

Here we see a swimming fish. By means of a tail and fins it pushes against the water and swims forward. So does a boatman in a boat, who, to move the boat forward, pushes the water back with a paddle.

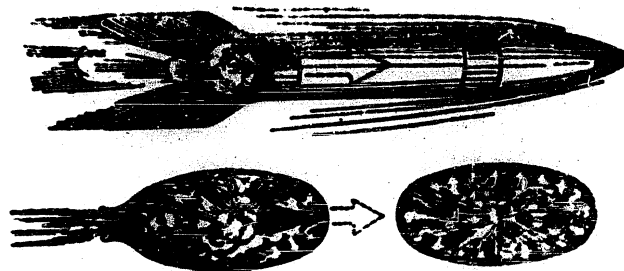


Fig.1 - Principle of Reaction Motion

A - The pressures of gases, created while powder is burned, on the opposite walls of the container is counter-balanced;

B - If the container has a gas outlet, the pressure on the back wall is unbalanced and reaction force is created.

C - The reaction force created while a reaction motor is operating moves the rocket.

Here we observe a pedestrian. He pushes the ground with his feet. Here the thrust (or the reaction force) cannot be perceived because the mass of the earth is unmeasurably greater than the mass of the man. Therefore, the motion of the earth is undetectable. By observing the motion of some animals, we can detect the reaction force at once. Those animals are inhabitants of water.

Here swims a cuttlefish. It sucks in water through its gills. Contracting, the walls of the gill cavity push it and the water flows out through the crater. The cuttlefish itself then moves to the side opposite to the direction of the water outflow. A mollusc which is called salpa is even more interesting. In the front part of its barrel-like transparent little body there is an opening through which it sucks water. By strong contracting motions of the right muscles, the water is

0 pushed back out through the second opening.
 2
 4 Hydrosreaction engines used in riverboats, which have received a name "water
 6 jets", operate under this same principle. By means of pumps, water is pumped in
 8 through an inlet in the front part of the ship and is ejected through the outlet in
 10 the kill, whereupon the velocity increases. The stream of the ejected water creates
 12 a reaction force which moves the ship. Deprived of the outer propeller, these ships
 14 are very convenient for navigation in low, clogged-up rivers.

16 Two forces are acting upon each other in a rocket. They are the rocket itself
 18 and the ejected stream of gases. It appears that the rocket pushes against the
 20 stream and as a result moves in the direction opposite to the direction of ejected
 22 gases.

24 Still in 1882, N.E.Zhukovskiy compiled a formula for determining the reaction
 26 of the ejected and inflowing stream of fluid. This formula gives an expression for
 28 the force of thrust (reaction force) developed in reaction mechanisms.

30 The second part of this work, which is called "On Reaction of Inflowing and
 32 Ejected Stream of Fluid", was published in 1886. In 1908, in the essay "On the
 34 Theory of Ships, Propulsed by the Reaction Force of Ejected Water", Zhukovskiy
 36 first calculated the influence of medium's resistance. Formulas introduced by
 38 Zhukovskiy in these works can be used at the present time too.

40 The origin of the movement of the rocket was well explained by Nikolay
 42 Ivanovich Kibalchich, the author of the first project of the powder rocket flying
 44 apparatus. "Let us imagine a cylinder", wrote he, "which is hermetically closed
 46 from all sides, except the bottom, which has an outlet. Let us place inside of
 48 this cylinder a piece of compressed powder and ignite it. Powder gases, created in
 50 the process of combustion, will press against the walls. But the forces pushing
 52 against the side planes of the cylinder will be counterbalanced and only the
 54 pressure on the upper closed wall is not counterbalanced.

56 But the gases emerging through the outlet on the bottom of the opposite side

0 generate a reaction force. If the reaction force, however, surpasses the weight of
2 the cylinder, it will move up".

4 Thus, we can say that the reaction force of rocket engines is the result of the
6 pressure force acting upon it.

10 3. Peculiarities of Rockets

12 We mentioned that a force which moves the rocket is generated in the rocket
14 itself; a gas stream is created as a result of the combustion of fuel stored inside
16 a rocket.

18 A rocket engine is an engine of direct reaction. In it, the fuel energy is
20 used for creating the propulsive force without any agents such as propellers, wheels
22 or fans, which are used in motors of indirect action. Exhaust is generated by
24 thrusting matter toward the side, opposite to the direction of motion.

26 It is clear that the movement can be created without the help of air, and
28 therefore a rocket can fly in a vacuum space.

30 In 1896, A.P. Feodorov offered an idea for a reaction apparatus which should be
32 moving by the force of gas-exhaust and did not require the atmosphere as a support-
34 ing medium. He called his book "A New Principle in Airnavigation, Which Excludes
36 the Atmosphere as a Supporting Medium".

38 Konstantin Eduardovitch Tsiolkovskiy writes that Feodorov's book has directed
40 him toward undertaking serious studies. In 1883 he expressed a thought on the
42 possibility of employing new rocket method of propulsion for traveling in the
44 vacuum space of the universe.

46 In his manuscript "Vacuum Space", which was found many years later in his
48 archive, Tsiolkovskiy offered such an explanation:

50 "Suppose there is a barrel filled with a high compressed gas. Provided one
52 of its faucets becomes open, then a continuous stream of gases will be issuing from
54 the barrel, also resulting in a continuous change of the barrel motion".

56 Several years later, Tsiolkovskiy mathematically substantiated the possibility
58

0 of the employment of rockets for a guided flight outside of the earth and was the
2 first to establish the basic theories for rocket motion.

4 The possibility of traveling in a vacuum space is the first peculiarity of a
6 rocket. This has been proved by experiments. Powder gases given off by the motor
8 were directed through a vacuum ring-shaped tube. The exhaust force of a rocket was
10 measured with an instrument. It was proved that the exhaust in a vacuum is greater
12 than in the air.

14 A rocket has another peculiarity.

16 A standard artillery shell does not become lighter in the process of a flight,
18 its weight does not change. In transportation machines, such as automobiles and
20 others, the change of the weight is inconsiderable.

22 A rocket uses a great amount of fuel and, noticeably, loses its weight during
24 the flight.

26 It is, therefore, a body of interchangeable weight and mass. So, for example,
28 a fighter-airplane with a rocket motor loses more than five kilograms of its weight
30 in one second, i.e. 20-30 times more than a conventional fighter.

32 A large long range rocket uses more than 100 kilograms of fuel per second and
34 becomes several times lighter toward the end of the motor operation.

36 This is another peculiarity of rockets.

38 Scientists became interested in studying the motion of the bodies of inter-
40 changeable mass a long time ago.

42 The Russian scientist, Ivan Vsevolodovich Meshcherskiy, introduced a theory of
44 the motion of interchangeable masses, which forms a new field in mechanics and is of
46 great meaning to modern technology.

48 The cases of motion when the mass of the moving body changes with time, are
50 very common.

52 Air navigators ascending in an air balloon carry a ballast. By ejecting gas
54 out of the cover and by disposing of some ballast, they regulate the ascent. The
56

0 mass of the air balloon, at the same time, changes.

2 An air balloon is an example of a body of interchangeable mass.

4 A rotating bobbin that winds or rewinds a thread, is an example of a body of
6 increased or decreased mass in motion.

8 A reaction water-jet ship, mentioned by us above, is also a body of inter-
10 changeable mass. Its mass increases while water is sucked inside and at the same
12 time decreases when the stream of water, which pushes the ship forward, is ejected
14 out of the ship.

16 Air-reaction motors have found extensive employment in modern aviation. The
18 air entering the motor is constantly ejected with the fuel which burns away. The
20 products of combustion are ejected at high velocity in the atmosphere, creating
22 reaction force. An airplane with an air-reaction motor is an example of a body,
24 the mass of which changes when in motion.

26 All rockets, rocket projectiles and torpedoes, aircrafts with rocket and
28 jet-reaction motors, are bodies whose change in mass in flight cannot be disre-
30 garded.

32 Therefore, the study of bodies of interchangeable mass in motion is of great
34 importance. Its value especially increased recently when the reaction methods of
36 propulsion started to be extensively used in aviation and artillery.

38 Bodies of interchangeable masses can be observed not only in mechanics, but
40 in nature too. Sea animals which move by the power of thrust produced by the
42 stream of water, which have been mentioned by us before, change their mass in the
44 process of motion.

46 Astronomers have observed long ago, that there are some deviations from the
48 movement of the moon, which was calculated by the law of celestial mechanics. It
50 was found that this phenomenon is caused by meteors. They bombard the earth and
52 the Moon, causing the increase in mass of both. The radius of the Earth, for
54 example, increases on account of the matter of falling meteors by one-half mm in
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0 a century. The Earth consequently is also a body of interchangeable mass.

2 We are protected from the "heavenly bombardment" by the armor of the Earth, i.e.
4 the atmosphere. A meteor, entering the atmosphere is a body of interchangeable mass.

6 The energy is constantly radiated by the sun. This energy is created by the
8 internal atomic processes which are taking place in the depth of the sun. The sun,
10 and all the stars, are also bodies of interchangeable mass. As we can see, the
12 cases when a body in motion changes its mass are very numerous in Nature and in
14 technics.

16 In mechanics, each body is assumed as a system of points. In order to study
18 the movement of the bodies of interchangeable mass it is necessary to study the
20 motion of a point of an interchangeable mass and to establish the equation of its
22 motion.

24 It was done by I.V.Meshcherskiy in the work "The Dynamics of a Point of an
26 Interchangeable Mass", published in 1897.

28 Meshcherskiy was the first to establish a basic equation for a forward motion
30 for a point of interchangeably moving mass. "Dynamics of a point of an inter-
32 changeable mass", said Professor A.A.Kosmodemoyanskiy, created by work and talent
34 of I.V.Meshcherskiy, still remains the most complete and substantial theoretical
36 study of the motion of bodies of interchangeable mass. This work, besides establish-
38 ing the basic equation, analyzes a number of original problems and gives some
40 methods, the development of which, will give, without any doubt, a line of prac-
42 tically important conclusions on the regularities in rocket dynamics".

44 Meshcherskiy was the first to establish the equation for the vertical motion
46 of a rocket.

48 In 1904, Meshcherskiy dedicated another work to the analysis of the movement
50 of a point in case of a simultaneous increase and decrease of the mass. With this
52 work, Meshcherskiy has laid the basis for a theoretical study of the motion of
54 flying mechanism with air reaction motors.

0 The Meshcherskiy works were much more advanced than the ones produced by the
2 science abroad where similar works were introduced much later. Ivan Vsevolodovich
4 Meshcherskiy is the creator of a new chapter in science of mechanics, the mechanics
6 of bodies of interchangeable mass.

8 The studies which considered the rockets as bodies of interchangeable mass were
10 developed and continued by Tsiolkovskiy.

12 Tsiolkovskiy analyzed the motion of simple stage cosmic rockets elaborately
14 and thoroughly. He proved that a rocket of this type can travel in space provided
16 that the supply of fuel is sufficient with respect to the weight of the rocket it-
18 self.

20 Tsiolkovskiy analyzed the motion of the rocket considering the influence of
22 gravity force and air resistance. He also studied the theory of movement of reaction
24 airplanes.

26 Continuing the study originated by Meshcherskiy and Tsiolkovskiy, Soviet
28 scientists accomplished a line of important works concerning rocket dynamics,
30 analysis of motion of rockets powered flying mechanisms as bodies of interchangeable
32 masses.

34 4. The Laws of Rocket Propulsion

36 Tsiolkovskiy developed a formula which now bears his name and has a great mean-
38 ing in rocket business.

40 It coordinates the velocity of rocket motion, created by burning fuel, the
42 velocity of ejected gases and the weight of fuel.

44 In his computations he assumed that the relative speed of ejected gases does
46 not depend upon the speed of rocket motion, as it is usually accepted concerning the
48 theory of rocket propulsion.

50 Provided the fuel supply is sufficient, a rocket can develop any given speed.
52 Tsiolkovskiy proves it with a simple example.

To simplify the computations we suppose that the weight is absent. For a unit we accept the mass of rocket without fuel. Let us assume that the amount of fuel is also a unit. The equal masses repulse equally from each other and develop equal velocities. Therefore, if the speed of the gaseous efflux is say 5 km in one second, the the rocket will develop the same velocity. If the rocket is carrying 3 parts of fuel to 1 part of its self-weight, then its velocity, as it is easy to prove, must double.

Actually, by ejecting first 2 parts of fuel, we impart to the other part of the rocket (of equal masses) a velocity of 5 km. Ejecting later the remaining 1 part of fuel, we impart the rocket (of equal mass) an additional velocity of 5 km, i.e. the final velocity equal to 10 km in one second. Generally, using the fuel consecutively:

1, 3, 7, 15, 31 parts

the final velocities of the rocket will be:

5, 10, 15, 20, 25 km in 1 sec.

But the numbers of the first line are the consecutive powers of the number 2 less 1:

$$1 = 2^1 - 1; 3 = 2^2 - 1; 7 = 2^3 - 1$$

$$15 = 2^4 - 1; 31 = 2^5 - 1$$

It is evident that with the increases of the relative amount of fuel in geometric progression (approximately), the velocity of the rocket motion grows in proportion with the arithmetic progression.*

*The above is approximate. The law of rocket motion (ignoring the force of gravity and the resistance of the medium) obtained by Tsiolkovskiy is mathematically ex-

(*continued next page)

The law of rocket motion established by Tsilkovskiy allows very important conclusions.

Provided the velocity of gases ejected from the rocket increases, then the velocity of the rocket itself increases also. Therefore, it is necessary to work in the direction of developing jets of the highest possible velocity and to produce fuel possessing high chemical efficiency.

Jet velocity of modern rockets is equal approximately to 2000 meters in one second. 5 times the increase of this velocity would be sufficient for reaching cosmic speeds by a large rocket, for example, a long range rocket which was used during the Second World War.

*continued from previous page
pressed as follows:

$$v = v_1 \ln 1 + \frac{M_2}{M_1} : \frac{v}{v_1} = \ln 1 + \frac{M_2}{M_1}$$

where v is the velocity of the rocket at the moment t ,

v_1 is the velocity of gaseous efflux with respect to the center of the rocket masses.

M_1 are the rocket masses without fuel;

M_2 is the fuel mass in the fuel line;

M is the fuel mass at the moment t ;

$\ln$ is the natural logarithm.

The highest velocity $V = v$ develops when $M = 0$ (when the entire fuel resource is consumed)

$$v = v_1 \ln 1 + \frac{M_2}{M_1} : \frac{v}{v_1} = \ln 1 + \frac{M_2}{M_1}$$

If the weight of the fuel increases (with respect to the weight of the construction of the rocket itself) then its velocity increases also. Therefore, the employment of light and durable materials for manufacturing the rocket parts will considerably reduce its overall weight.

In the modern long-range rockets the ratio between the weight of the fuel and overall weight of the rocket is 0.7 and the final weight is equal to 3. The highest speed developed by the rocket at the end of motor operation is about 1500 m in one second. The speed developed by a two-stage complex rocket is 2250 m in one second or 8100 km in one hour.

Rockets, thus, open new possibilities in the development of high speed motions.

5. A Rocket and a Projectile

A projectile is fired out of a gun. At the discharge it receives only an initial push. During the flight it is not subjected to any action.

The force of gravity and air resistance reduce the speed of the projectile and force it to fall to the ground.

Upon the rocket, while the motor continues to operate, acts one more force, the reaction force. Its velocity, therefore, in flight does not decrease but increases as long as the process of burning continues.

This peculiarity of a rocket projectile can be used, for example, in shooting under water or from under the water.

Water if compared with air has higher density. At the moment when the water medium is reached by an artillery projectile, it loses its velocity rapidly and consequently its power before the target is surprised.

In the case of a rocket projectile the matter is different. It will move toward the target as long as the motor continues to operate and the process of combustion goes on. While closing in on an enemy ship or a submarine, it reaches the target at a velocity sufficient for surprising.

We know that a discharge from an artillery gun continues only several thousandths of a second. The projectile develops high speed exactly at these moments, i.e. during this negligible part of a second when the discharge occurs.

The speed rapidly increases from zero to the enormous magnitude. But the increase in speed is acceleration. Acceleration, therefore, becomes exceedingly high, i.e. tens of thousands times greater than the acceleration of the gravity force on ground.

A man cannot accomplish a flight when inside of a projectile, no matter how large the projectile is. High and sudden acceleration is harmful for the human organism; it is experienced as an increase in self-weight.

That is why the heroes of Jules Verne's novel "Out of the Gun to the Moon" would not survive through the moment of discharge. They would be demolished by the force of self-weight which would increase several tens of thousand.

A rocket opens a possibility for a manned-high speed flight and at the same time eliminates deadly overweight. *During the flight, the velocity develops progressively and acceleration does not reach magnitude critical for organism. For example, the largest modern rocket develops acceleration 6-8 times greater than the acceleration of gravity force on the ground. Such and even greater acceleration, but of short duration, developed in field speed aviation can be withstood by a human being.

Acceleration produced in guided rockets can be regulated and, thus, a constant level suitable for men ascertained. High acceleration affects not only men, but also instruments, handicapping their operation. If we had a desire to install some measuring instruments and guiding devices in an artillery projectile, they would not operate. Only radar fuses* can withstand tremendous overload created at the discharge.

*The radar fuse is a minute receiving-transmitting radiostation which can send

Comparatively low acceleration developed by a rocket permits the use of instruments, and in stratospheric rockets also of instruments intended for scientific research.

By using new lighter materials, the body of a rocket projectile can be made with thinner walls, and then, by winning on body weight, it is possible to increase the load or the propulsive force and consequently increase efficiency, i.e. range.

While analyzing the types of rockets and their designation, we mentioned other very important qualities of rockets as a weapon, its simplicity and light weight of launching stands, which assert the maneuverability. This permits installing them in automobiles. This installation can be multi-barreled, permitting mass firing.

The absence of recoil made the rocket-weapon especially valuable for armament of such combat mechanisms as airplanes, tanks and landing boats.

A long-range rocket-weapon assures a range of shooting which cannot be reached by any conventional artillery means.

Let us indicate that along with advantages, the rocket-weapon has its disadvantages too.

The principal disadvantage is lower accuracy in comparison with action of artillery projectiles.

This disadvantage has been considered as a factor against the use of rockets. "Rockets do not have the accuracy of actual artillery", wrote General Vorontsov (who commanded special Caucasus corps) in the middle of the 19th century. And,

*continued from previous page

radiowaves several centimeters long into space. The entire station antenna and accumulators can be mounted in the head of a projectile. When the projectile approaches a target (airplane or a ship) approximately on 15-20 m distance, the waves reflected from it actuate the fuse. The projectile explodes and its fragments hit the target.

really, then the rockets were inferior in accuracy to the smooth-muzzled guns, and later to the rifled guns. Modern rocket projectiles are also inferior in the accuracy of firing to the artillery projectiles. What is the cause of it?

The cause should be looked for in the peculiarities of rocket motion.

The entire flight of a rocket can be observed consisting of ten parts. The first part is the flight with operating motor. A rocket is accelerated along the guiding rails or climbs from a launching stand propelled by reaction force. When the motor becomes switched off, it continues a free flight like a projectile thrown out of a gun. The second part of the flight is similar to the flight of a regular projectile.

It is impossible to direct the reaction force exactly along the axis of the rocket because it is impossible to manufacture a precise motor which would ascertain a uniform gas flow. There will always be some causes for deviations. One of the causes of inaccurate flight can be produced by non-coincidence of the direction of the reaction force with the axis of the rocket. As the result, the accuracy of rocket projectiles is lower than that of regular ones. It becomes understandable if we recall that they are acted upon by an additional force - the reaction force. The deviations which are developed under the action of reaction force lead them away from targets.

Many attempts to eliminate these defects had been made. Konstantinov, scientist artillerist of the past century, indicated basic principles securing stable flight from a rocket projectile. He wrote that from the very first time when rockets were introduced in European armies, there were accomplished some investigations on achievement of stable rocket flight by imparting rotating motion about the longitudinal axis. Experiments were carried with rockets attached with tails and tailless. Rotating motion was reached by various methods: by employing air resistance, by directing air through slanted feathers mounted on the body from

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outside, by means of launching tubes with threaded inner surface which accommodate catches attached to the other side of the rocket; by means of gases ejected through the threaded canals, which are situated in a cover, which encloses the rocket chamber from underneath.

In modern Rocketry old ideas are realized in a new way. Feathered rocket projectiles become the successors of the old "rocket with feathers" and wooden tails. Tail feathering, i.e. stabilizers, keep the rocket in balance during the flight. Sometimes, slant mounted feathering is accepted; then the rocket rotates in flight due to air resistance.

Rotating projectiles (they are called sometimes turbo-reaction) found a very extensive employment. The tail feathering in this case is substituted by a row of slanted canals for gas outcome. It is similar to a special "rocket-turbine"; gases emerging from such nozzles rotate the rocket about its longitudinal axis. Of course, this rotation consumes a part of the fuel and evidently reduces the range.

In the process of rocket development there were old ideas revived and new ones created.

A flight of long-range rockets and rocket aerial torpedoes is controlled and directed by radio. To guide the flight of such rockets, telemechanical and automatic means are employed.

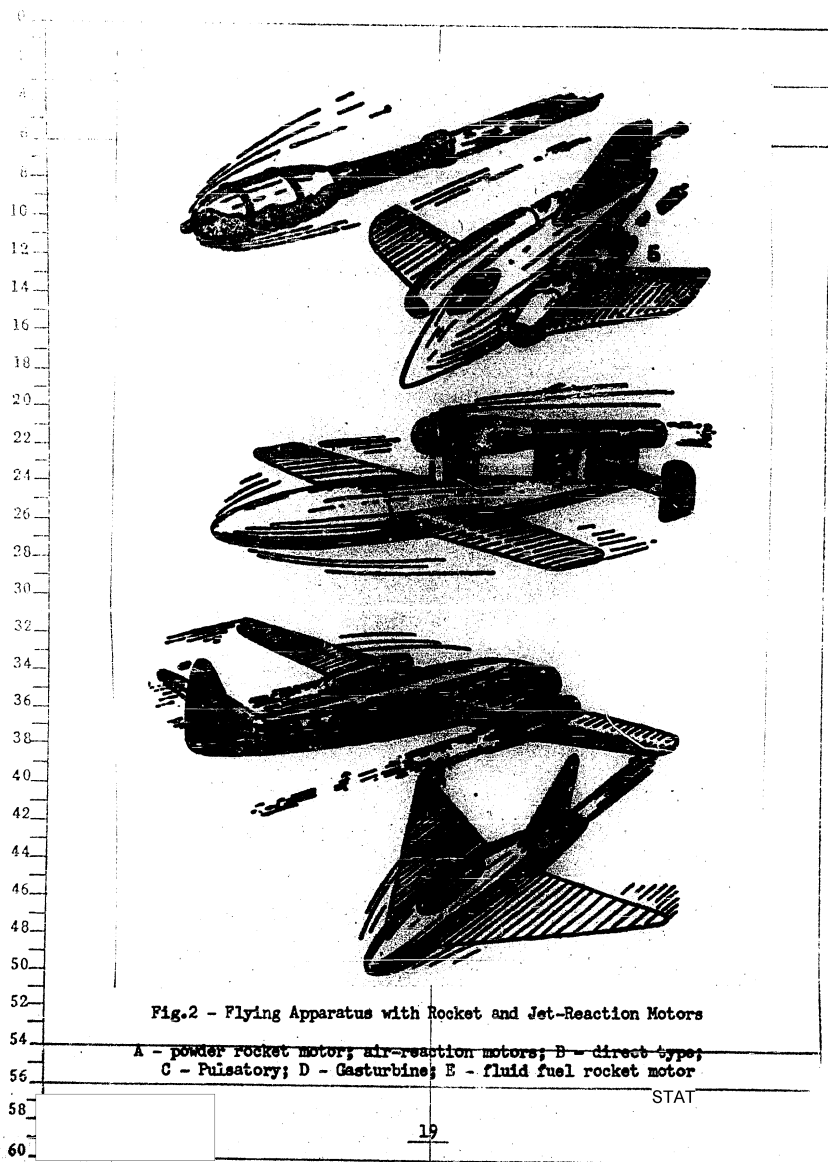
A radar fuse greatly improved the firing efficiency of rocket projectiles.

Poor accuracy of fire was the principle cause which brought out the decline of rocket-weapon in the end of the 19th century. Artillery which employed threaded muzzles and black powder was more accurate and had greater range than the rockets.

The First World War began. Powerful and long-range projectiles were required for demolishing enemy fortifications. The larger is a projectile, the greater is its range, the costlier is the gun and lower is its maneuverability. New type of troops - aviation - demands light and recoilless arms.

Naturally, after the First World War the rocket was thought of.

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By returning to the old arms, the rocket, military technique, however, progressed not backward, but forward.

Smokeless powder which is more efficient than the old black smoking powder started to be employed in rockets.

New durable, but light, alloys started to be used for rocket manufacturing. Widely developed metal working industries were effective enough in rocket projectile mass production.

Though the accuracy of rocket projectiles, under the circumstances described by us previously, still needed improvements, this defect could be balanced by the quantity of fire.

And, if before rockets were used separately, now this method of firing is employed only in anti-tank rocket rifles and aviation rocket installations.

But powerful and concentrated fire of rocket mortars assists the "Queen of Fields" - the Infantry.

6. Rocket Motors

Half a century ago there existed only one type of rocket motor.

That was a powder rocket motor.

A powder rocket motor is still used in Rocketry extensively. Its working principle is very simple. It is intended where a strong exhaust of short duration is required, i.e. in rocket projectiles, torpedoes, start boosters, aerial torpedoes and rockets.

Powder is still the only solid fuel which is used in rocket motors. Rockets, however, which use solid fuel, except the powder type, did not find extensive employment. The attempts to use coal in the form of discs enclosed in the combustion chamber and also the use of dust fuel were carried out.

We can imagine some motors using partially solid propellents, partially gaseous or liquid (oxidizer) and even such using one part of liquid fuel and the other a gas.

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Motors which use liquid fuel and gas oxidizer, i.e. oxygen from air (called reaction motors) are most widely employed. They are used mostly in aviation as airplane motors. Air, which enters the motor, is compressed by dynamic air pressure in flight (in motors of direct action) or by a compressor which is operated by a gas-turbine (in a turbo-compressor motor). The fuel burns gradually in motors of direct and gas-turbine types; or, periodically in the combustion chamber enclosed by a valve grindle (in motors of pulsatory type).

Air-reaction motors are also employed in artillery, in aerial torpedoes and some types of projectiles and rockets.

Finally there exists one more type of rocket engine, in which both parts of the propellant - fuel and oxidizer - are liquids. Such liquid fuel motors are employed in artillery, in rocket projectiles, aerial torpedoes, long-range rockets, and in aviation - as boosters and engines for airplanes. (Fig.2)

Liquid fuel engines are installed in stratospheric rockets and in the future they will find employment in high altitude and high speed aviation.

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SECOND STORY

THE OLDEST AND THE YOUNGEST WEAPON

1. From the Chronicle of Soviet Rocket Artillery

The rocket artillery was introduced as an armament of the Soviet Army during the first days of the Great Patriotic War (Fig.3).

Let us turn over the pages of the glorious history of the combat achievements of the Soviet rocket artillery.

The enemy was stunned by the new terrifying weapon. Thinking that they faced a great number of guns concentrated in one place, horrified Germans were abandoning their positions. Not only the soldiers who were under direct fire but also those who occupied side, distant positions, were retreating.

The Fascist command was greatly alarmed by this new threatening weapon and ordered its troops to report captured "automatic firethrowing guns" immediately in the same day, to "the general, commanding smoke screening units attached to the Commander in Chief of the Army".

But this was only the beginning.

During the severe battle at the "under Moscow" regions, guard mortar regiments were the first to demonstrate the tremendous destructive force of their weapon - rocket mortars, whose concentrated fire greatly handicapped the enemy armies.

Especially high were the enemy losses caused by the fire of the rocket artillery.



Fig.3 - Rocket Mortars

ery in regions where the enemy's army was accumulated.

Rocket mortar subdivisions were the cause of many unsuccessful attacks undertaken by the enemy and they assisted the destruction of the German-Fascist armies at Moscow.

When our armies started the offensive on this part of the front, the regiments of the rocket artillery followed the retreating enemy, demolishing its man power

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and machinery.

In this period, our troops were overcoming a number of defense lines constructed by the Germans. The rocket artillery successfully accomplished a new mission, i.e. the demolition of the enemy's defense lines.

Rocket artillery units greatly assisted our ground forces during the next six months battle at Stalingrad, whose development was followed by the whole world with unremitted attention.

During the first days of the German advance toward Stalingrad, rocket artillery regiments caused the enemy great losses and were covering our retreating armies.

With the beginning of street fights, the tactics of the rocket artillery were changed. The freedom of the maneuver was limited, the number of possibilities for the employment of concentrated fire became smaller. Guardsmen - mine throwers - started to fire at the enemy by direct pointing. Their terrible weapon has proved its usefulness here also; its destructive force became especially evident.

In November 1942, the enemy's defense lines were broken and the surrounding of the Stalingrad group of the German army began.

The regiments of the rocket artillery, at the time, directed their destructive fire at the enemy, depriving him of any possibility of assisting his surrounded parts. The Germans were forced to transfer to the battlefield mechanical and manpower from the other parts of the front. In spite of that, the counterattack was brought to a halt and the surrounded group was demolished.

In battles at Moscow and Stalingrad, the young Soviet rocket artillery gloriously accomplished its first mission and conquered a right for respect and love in the Army, and created anxiety among the enemy.

The power of the rocket artillery is in its concentrated fire, in the ability to cover a large territory with fire, and in the destructive force of its fire.

During the defensive battles, the rocket artillery regiments participated in

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0 firing at ranks and accumulations of the enemy armies, taking part in the artillery
2 preparations, were handicapping the enemy attacks, assisting our armies' counter-
4 attacks, conducting firing by direct pointing and demolished not only man power but
6 tanks also.

8 Combat characteristics of our new weapon became evident especially during
10 victorious offensives. Following the enemy continuously, rocket artillery regiments
12 demolished man power and armament, destroyed defense lines and knots of resistance,
14 beat off the attacks of the retreating enemy. Very often, rocket artillery units
16 were forced to conduct a fight against the enemy that was consolidated in winning
18 positions. Guardsmen of mortar units were the victors of these fights.

20 Guardsmen of mortar units had mastered the weapon to perfection and assisted
22 our armies under all circumstances. They extended great help during the battles
24 for large cities on the territory of the enemy, which was transformed into the
26 strongholds of defense where every building was adjusted for a continuous defense.

28 Rocket artillery proved itself as the weapon which was capable of destroying
30 structures and other knots of resistance by methods of direct pointing, transform-
32 ing them into piles of ruins.

34 Battles for Berlin, where rocket artillery regiments took an active part, were
36 the last battles of the Second World War.

38 "Rocket artillery was a terrifying weapon which delivered severe blows upon
40 the German-Fascist intervents. Guard rocket artillery units that were courageously
42 fighting the enemy, demonstrated the sample of virility, resistance and heroism,
44 honorably confirmed the high title of the Soviet guardsmen given to it and covered
46 its banners with unfading glory in war process. The Guard units became stronger and
48 acquired a rich combat experience and together with our entire artillery have
50 grown into a powerful force, capable of defending the freedom and independence of
52 our beloved Fatherland", we read in the chronicle of the Soviet rocket artillery.

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2. Powder Rocket Motor

A powder rocket motor has one remarkable characteristic - its simplicity.

It is assumed that in every motor something must be moving, something rotating.

A powder rocket mover has neither rotating nor moving parts.

Only one liquid fuel rocket motor with a balloon type of feed, where the fuel is injected under the pressure of compressed air, can compete with the mover of this type.

The powder rocket mover was unique for a long time. It is considerably older than the other rocket motors and in the several centuries of its existence it underwent considerable changes.

We have to mention that this mover, virtually, consists of one chamber which at the same time is a fuel storage and combustion chamber. That is why the rocket mover is very often called a rocket chamber.

First, the rocket chamber was solidly filled with compressed powder. The charge was ignited at the end, preserving constant burning surface.

Later there were introduced rockets which used a charge of powder with an inside furrow. The burning surface increased during the process of combustion; more gases were produced with a force of increased power.

The chamber was closed with a bottom plate with "glasses", i.e. gas outlets. To increase the burning surface and secure an even process of powder burning, the blocks are usually made hollow. The shape of the blocks in cross section can be different - round or star-shaped, etc.

As a result, a constant pressure in the chamber and constant velocity of gaseous efflux can be maintained.

To increase the efficiency of the motor, the powder charge can be armor-plated, i.e. covered with a layer of a compound which resists burning and limits the burning surface.

The chamber is enclosed with a diaphragm, i.e. a partition with openings which

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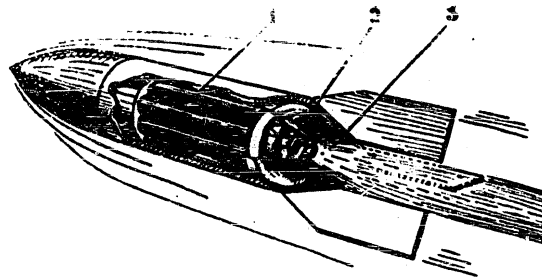


Fig.4 - A Modern Powder Rocket Motor

1 - Powder Blocks; 2 - Diaphragm; 3 - Nozzle

keeps the unburned parts of the charge inside of the chamber.

At the discharge of a projectile, the blocks are ignited by an electric ignition device. The spark ignites the compound which in its turn ignites the charge in the chamber.

It is worthwhile to indicate that such powder rocket motor is very similar to a rocket invented by Kibalchich and which had small compressed cylinders in the chamber.

The temperature in the rocket chamber reaches 2000°C and the pressure 100-300 atmospheres. Let us indicate that the pressure in the canal of the bore of an artillery gun reaches up to 2500-3000 atmospheres. As we see, the pressure in the combustion chamber of the powder rocket projectile is considerably lower.

Simplicity is the most important advantage of the powder rocket motor. It has, however, its disadvantages, too.

The operation time of this motor fluctuates from several fragments of a second to 1-1½ minutes. It is extensively employed in artillery and aviation, but is limited to the cases not requiring any guidance during the flight (projectiles,

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boosters).

A powder motor which could be shot off and started again is theoretically possible but practically not employed. The regulation of exhaust in flight is very complicated.

For feeding the powder in the chamber, inventors have constructed a mechanism, reminiscent of one which is used in the semi-automatic revolver "Nagan". A rotating cylinder alternately feeds the charges into the chamber. One inventor even designed a rocket dirigible with a "revolver" of this kind. But all this does not solve the weight and construction problems.

Therefore, we can say that the powder rocket motor is a motor of single action, of short duration and is intended where action of this kind is required, i.e. in projectiles, starting rockets, for the assisted take-offs, etc.

3. Powder as a Fuel

The simplest solid propellant, which has been used in rockets since long ago, is black smoky powder (a mixture of potassium nitrate, carbon and sulfur). Here carbon serves as a fuel, potassium nitrate as an oxidizer, i.e. it supplies oxygen which is required for the process of combustion. Black powder, however, has a considerable disadvantage; its combustion products are approximately $2/3$ solid particles, which, mainly, produce the clouds of black smoke. These solid particles reduce the velocity of the gaseous efflux.

When smokeless powder was invented, this disadvantage was eliminated almost completely. The velocity of the exhaust developed by burning of the smokeless powder is approximately two times of that developed by burning smoky, black powder.

Here a question can arise: is it possible to use in rockets some other explosive substances, which also contain oxygen? To these substances belong, for example, dynamite, trotyl, and others.

Evidently not, even if they are compressed as powder.

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These substances decompose so vigorously that an explosion is inevitable. That is why only powder can be used in rockets operating on solid fuels.

The designation of a propulsive charge is not to explode the rocket but to move it forward. An explosion is almost instantaneous combustion. To eliminate it, it is necessary to slow down the process of combustion and to establish a gradual burning, layer after layer, of the powder charge. For this purpose a black powder charge is compressed under high pressure and more sulfur is added to reduce the velocity of gas production.

Grains of powder-like, black smoky powder are of a very fine texture and that causes a large burning surface.

The entire thickness of the charge becomes ignited at once. Otherwise, here occur the same processes which take place at the discharge of a gun.

This can be eliminated only by compressing black, fine-grained powder. But the presence of a little fracture in the charge is sufficient to produce an explosion instead of a gradual burning, due to the gases accumulated in it. By the way, this caused the combat rockets to explode on launching stands and before the targets were reached.

Academist A.N.Krylov recalled:

It happened in 1908. I was then a president of a Navy Technical Committee. There was an engineer - Colonel Gerasimov - who had connections in many spheres. Once he invented a rocket which was intended to fly at a great distance and could carry a projectile.

He was given all the necessary means for the realization of this project. He built it and stated that on a certain day at the Okhtenskiy navy range he would conduct the test.

I went to see it. The rocket was made of steel, it was about $1\frac{1}{2}$ yards long, its diameter was approximately 8 inches and it was filled with a powder filler. It did not have any tail, but to secure the stability, he attached to it a butterfly nut

similar to a ventilator and with a pilot knob upon it; this gyroscopical device was intended for stabilizing it during the flight.

He arrived at the polygon and installed his rocket stand. After we examined the entire device he asked: "Well, will you give permission to ignite?" "No, you may not. Here, on the polygon you can ignite a rocket only from out the blindage. Even when firing from an inspected gun, all people must be in the blindage and the discharge is conducted by galvanization along a cable from the blindage".

The cable was conveyed, attached and the igniter was connected to the rocket.

Gerasimov asked us: "Where are your observers?" He was told that they are placed approximately 18 versts apart. "That is exactly how far it will fly", said Gerasimov. He switched on the current and we could see a cloud of smoke coming from the blindage. We approached the place and could not find either stand, or rocket, nothing but pieces.

In the 20's, when many experiments were conducted with rocket automobiles of various kinds and trolleys, explosions could be heard very often.

Smokeless powder does not have a grain structure similar to that of black smoke powder, which consists of separate particles of carbon, potassium nitrate and sulfur. The ingredients of smokeless powder are ground and intermixed in such a degree that instead of separate grains of different substances there is a homogenous mass of identical properties. Each particle of smokeless powder contains both fuel and oxygen. Each particle of smokeless powder seems to substitute the particles of carbon, potassium nitrate and sulfur.

Smokeless powder has a close and homogenous texture. It is of gelatinous structure but harder and more durable than that of regular gelatin. It always burns gradually, layer after layer, without producing hard particles of smoke and scale formations.

Only a very high pressure in the chamber can cause explosions. But, usually, the pressure developed during the motor operation is considerably lower and that

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prevents this danger.

The operation of the powder motor, however, depends upon the temperature of the air and conditions of powder conservation. The value of exhaust depends upon the temperature. A charge can change its properties during the period of conservation and that consequently affects the flight. These peculiarities must be considered when solid fuels are used.

It is necessary to indicate that the biggest honor in creating the best, for its time, sample of smokeless powder, belongs to a great Russian scientist, Dmitriy Ivanovich Mendeleev.

Chemists have improved powders, trying to reach greater velocities of gas ejection. Soviet engineers were the first to create smokeless powder for rockets.

The powder has changed the rocket. The development of new materials became necessary because the pressure in the combustion chamber of a rocket projectile has increased several times. New materials and new powders helped to create a new powder rocket.

4. History of the Powder Rocket

The early period of development of the Russian rocket is not studied adequately. "The Greek Fire" mentioned in the historical studies was made to work through the use of a rocket solution. Therefore, the first Russian rocket, most probably, was in use as early as the 10th century. It is also possible, that incendiary rocket projectiles were employed in the battle described in "Story of Igor's Army" (12th Century). Rockets are mentioned in the Pskov chronicle (15th Century). The manufacturing of powder in Russia can be traced back to the 15th Century; it is possible that the manufacturing of rockets began at that time too.

Incendiary and firework rockets were very popular in the 17th Century. In the 17th Century, Onicim Mikhailov compiled "A Code of Military, Cannon and Other Actions, Concerning Military Science", which explains methods of manufacturing and

launching rockets and their combat employment.

In the 17th and 18th Centuries, rockets were often described in military literature. The fields of combat employment of the rocket weapon and the technology of its production were described in Russian military essays. The development of gun artillery in the 18th Century forces rockets to the background, however. Only in the end of the century they have found employment in colonial wars.

In Indian armies, at that time, special units were acting against Englishmen. The English engineer, Kongrev, who became practically acquainted with rockets in India, introduced them as an armament in England and this example was followed by other countries. Rockets were used in the epoch of Napoleonic wars and in spite of their imperfection, were of some help.

So, for example, during the siege of Buloon, the englishmen were firing rockets from ships, trying to set the city on fire (Fig.5).



Fig.5. A City Subjected To Rocket Fire From Ships

Later rockets were extensively employed by European armies. Various types of rocket projectiles were developed.

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The 19th Century was a century of violent development of rocket technology in Russia.

The Russian rocket industry progressed along its own path.

However, the names of the creators of the Russian rocket weapon remained unjustly forgotten for a long time. And only now, thanks to the works of the Soviet researchers, their names started to occupy honorable places in the history of our rocketry again. The name of Lieutenant General Alexander Dmitrievich Zasyadko must be mentioned first.

The creators of the Russian rocket weapon - A.D.Zasyadko and K.I.Konstantinov - have created in the past century original samples of rockets which surpass foreign rocket armament in quality. Russian combat rockets were successfully employed in military actions during the Russo-Turkish War in 1828-1829 and in other companies.

It is necessary to mention that before Zasyadko, there were in Russia people who were interested in rockets. Masters of rocket manufacturing existed in Russia since long ago.

Still in 1680, in Moscow, the first "rocket establishment", where the formulas of rocket compounds were analyzed and rockets manufactured, was created.

Still in 1717, a signal rocket was introduced for the use in the Russian army. It served truthfully for almost two centuries.

Foreigners were stunned by the art of the Russian pyrotechnics, the production of powders, fireworks and signal rockets.

"It is hard to describe the amount of powder used during dinners, entertainments, gay celebrations, at holidays and salutations,...because in Russia, sand is not more valuable than powder and perhaps there is no country where it is manufactured in such quantity and where in quality and power it could be compared with the powder of this land", - so wrote the Danish ambassador to Russia, Yu. Yul'.

In Russia, in the beginning of the 19th Century, the manufacturing of firework rockets was on a high level of development.



50. Zasyadko, Alexander Dmitrievich (1779-1838). He was born in the village of
 51. Lutenko, Poltav region. He served 15 years in the acting army. Served with Surovov
 52. and Kotuzov armies. Was working on the development of combat rockets since 1815.

53. In 1820, he was the head of the Artillery School, the Saint Petersburg Poly-
 54. technical Laboratory, powder factory and arsenal.

55. The employment of rockets during the war with the Turks in 1828-1829 was organ-
 56. ized under his direction and immediate participation.

57. He retired in 1834 and worked on the problem of navigation at the Dniepr
 58. rapids.

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The masters of this field - M.V.Danilov, F.S.Cheleev and others - left a series of printed works which described the working principles of the rocket, the methods of their refill, formulas for powders and some other data.

Books, written in the 70's of the 18th Century by Major of artillery M.V.Danilov, preserved their value for many years after.

General Alexander Dmitrievich Zasyadko was one of the first who valued a rocket as a combat weapon. He designed two types of rockets: demolition and fragmentation types; improved the technology of their production, designed a special stand for rocket launching. The flying distance of the Zasyadko rockets in particular cases was up to 3 km for four inch rockets and 1.6 km for two inch rockets (Fig.6).

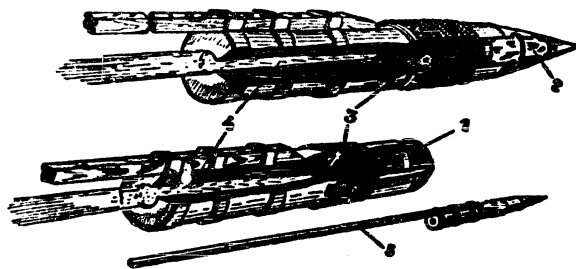


Fig.6. Combat Rockets of A.D.Zasyadko
1 - Grenade; 2 - Incendiary compound; 3 - Rocket compound;
4 - A forrow in the rocket compound; 5 - Tail.

Zasyadko, as it was described by his biographer, tried to benefit his country "...not making a mystery of his invention, nor demanding any rewards for expenses, he submitted a detailed description of his invention to the authorities and ex-

plained its benefits to the Fatherland..." which could be received from the employment of combat rockets in warfare.

All of Zasyadko's works were conducted on money received from the sale of his estate.

The rocket tests were successfully accomplished and they were accepted for the armament of the Russian army. Zasyadko was directed to Field-Marshal Barklay de Tolly, to supervise the rocket training of officers.

In the beginning of the Russo-Turkish War in 1828-1829, special rocket units were organized. At that time, 36-, 20-, 12-, and 6-pound rockets and corresponding launching stands, including stands for launching 6 rockets simultaneously, were manufactured.

When the war began, Zasyadko himself went to participate in the action of the army. An additional production of rockets was established through his energetic actions and people trained in rocketry were directed to the battle grounds. A special rocket unit which was organized before the war, also participated in the battles.

Ships of the Black Sea and the Danube Navy were armed with rockets also.

The rocket weapon was successfully employed during the siege of Varna, Braulova, Akhalzyka, Silistria and other cities and fortresses of the enemy.

That is how, through the energetic activity of General A.D.Zasyadko, the Russian rocket has received its first combat baptizing.

The action of the rocket during the siege of fortresses was thoroughly studied by Russian military engineers. They analyzed the efficiency of the rocket weapon in action against fortifications. They found new fields of employment for the rocket projectiles. General A.A.Shilder deserves the honors for the construction of the first submarine in the world, armed with rockets and development of anti-mine system with the employment of rockets in the defense of fortresses.

The future development of the combat rocket is closely connected with the

name of Konstantin Ivanovich Konstantinov.

K.I. Konstantinov became interested in rockets when he was a cadet of the Mikhailovsk Artillery school (now the Academy for artillerists) which he entered in 1834. Soon after he was graduated, in 1840, K.I. Konstantinov was sent abroad to study rocket manufacturing in countries of Western Europe. During this voyage Konstantinov was convinced that the organization of rocket business in foreign armies is not better than in Russia, and in some respects even poorer.

So, when in London, Konstantinov was offered, to buy for Russia, a factory producing "The Congreve Rockets"; he, upon its examination, declared:

"The Congreve secrets are no secrets to us any more, and the London factory in my opinion is an ancient establishment which is of no interest to us".

When Konstantinov returned to Russia, he was assigned to the Staff of the Staff of the Commander of Artillery. At that time Konstantinov accomplished a line of inventions, which were used in artillery (a device for determining the initial velocity of projectiles, mobile sight and others). Besides that he conducted a study of powder properties at the Protechnical School.

An electroballistic device and rocket ballistic pendulum, invented by Konstantinov (1844-1853), greatly influenced the development of the rocket technique (and are still valuable). The latter is used to study the reaction force and the time of its action. "I used the device" wrote Konstantinov, "it is the most accurate and is intended in research for measuring time. That is why I constructed a ballistic pendulum for rocket use".

With the help of this pendulum Konstantinov undertook a number of studies. Through the employment of rocket pendulum, many important conclusions concerning the construction of rockets were drawn and their ballistic qualities were improved.

Facts received from the observation of the rocket operation indicated the necessity of establishing rocket ballistics. "Facts related to the ballistic properties of rockets represent a series of observations, but even they can indicate



Konstantinov, Konstantin Ivanovich (1817-1871). About 1836, the Michailov Artillery began to use rockets. 1840-1844 he belonged to its staff. In 1848 he specialized in pyrotechnics and rockets. In 1850 he was given the command of the St. Petersburg Rocket School, where he remained until 1871.

the possibility of developing the theory of construction and firing rockets, generally, the possibility of rocket ballistics" - wrote he.

But first of all it was necessary to improve the construction of the rockets and their manufacturing.

In 1850, Konstantinov was given a post as a Commander of the Petersburg rocket establishment.

This inheritance was a very poor one.

The rocket establishment, in fact, was a domestic workshop which employed thirty workers. Neither mass production of rockets, nor their high combat quality, nor any kind of research work, was possible. But Konstantinov's energy overcame all encountered handicaps.

Konstantinov started the reconstruction of the Petersburg shop substituting the hand method of refilling the rockets by a hydraulic method where the pressure could be regulated, invented by him. He constructed a machine for boring canals in the powder charge and other devices, to abandon the manual operation.

Konstantinov also introduced some changes in the construction of rockets. After a row of experiments was accomplished, he substituted a curved bottom plate for a flat one. He composed new, more efficient powder compounds intended for rockets. He established an order in the production of rockets by limiting it to two main types of combat rockets - explosive and incendiary - and accepted three basic calibres instead of a number of voluntary ones (Fig.7).

The improvements, introduced by Konstantinov, produced remarkable results: the range increased four times. The rocket manufacturing acquired a mass character and reached a volume quite unusual for the time.

The Konstantinov's works in the field of rocket artillery were widely known. In 1859 he was appointed "Director of the Manufacturing and Employment of Combat Rockets".

Inside of the walls of the Saint-Petersburg establishment, a voluminous work

on the improvement of life saving rockets was in progress.

In 1862, Konstantinov constructed a rocket carrying a charge with two furrows and that construction secured gradual burning of rocket charge of longer duration

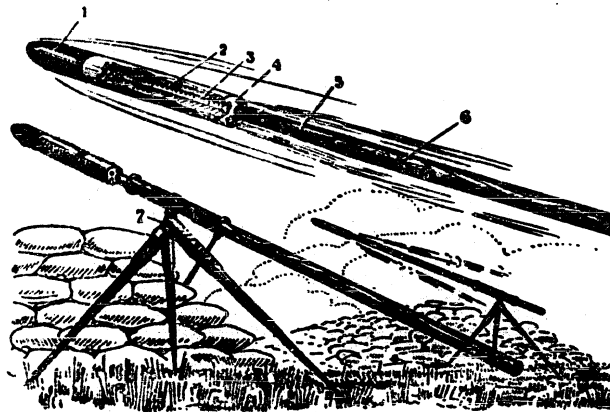


Fig. 7. Combat Two-inch Rocket of the Konstantinov System
1 - Grenade; 2 - Rocket compound; 3 - The furrow in rocket compound;
4 - Bottom plate with glasses; 5 - Tail pipe; 6 - Tail; 7 - Rocket
launching stand

than in the case of standard rockets. The trajectory of rocket flight was less steep and it could transfer a long and thin cable. Its range was $1\frac{1}{2}$ times the range of an English lifesaving rocket, which was considered the best. Four stations situated on the coast of the Baltic Sea were equipped with life-saving rockets of the Konstantinov system. The method of the transfer of a life saving cable by means of rockets is used at the present time.

Signal rockets which were manufactured in the Saint-Petersburg rocket establishment had better quality than similar rockets of foreign brands.

Lieutenant-General Konstantinov was not only the creator of rockets but also a passionate propagandist of rocket weapon.

His numerous articles on different fields of Rocketry were published in the

pages of "Artillery Magazine".

Konstantinov accomplished a serious job in rocket training of artilleries.

Konstantinov established an academic course, "Combat Rockets", which was widely known. The conclusions drawn by Konstantinov from the study of the vast, actual material, were put as the basis of a new military subject - The Tactics of the Rocket Weapon.

Konstantinov assumed that to expect any detectable results "it is necessary to develop out of it (i.e. from the rocket weapon - B.L.), a separate independent weapon, and to assign the rocket to persons who are exclusively in charge of rockets".

At the same time he understood well that the rocket cannot be employed in all cases of combat action and cannot replace the gun artillery.

"Rockets", - wrote he, - "never and in no respect can completely replace guns, but they can be used as an artillery weapon, the absence of which will always be regretted". He indicated that rockets are of special importance for "landing on shores, in mountain flights and in trenches, they have an indisputable advantage".

Konstantinov was forced to a vigorous opposition against bluntness and inefficiency of the czarist officials. They opposed the wide employment of rockets during the Zevastopol campaign, when a rocket could be of great help. The rockets were employed only in limited actions during the siege of Sevastopol in 1854-55. The rocket unit of Russian seamen successfully acted in street fights.

Imprisoned French officers witnessed that several incendiary bombs dropped in the midst of ships harboring in the Kayshevoy bay would be enough to deprive the whole army of allies of medium of existence in Crimea.

In the 60's, Konstantinov started a project of a new mechanized rocket factory with laboratories, proving grounds, study center, which would be a powerful industrial and research base, so necessary for the future development of the rocket weapon.

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The construction of this factory has continued for eight years and later, the Petersburg rocket establishment was transferred to Nicolaev.

When, finally, the factory was erected, the nearsighted czarist government lost the interest in rockets, because rifled guns began to be used in the Russian army. The Nicolaev factory was redesigned for other purposes. Later it was manufacturing illuminating flares.

Konstantinov who moved to Nicolaev when the construction of the new factory began, died in 1871.

Konstantinov's name will always be remembered in connection with the history of the rocket weapon.

Famous "Katyusha", which horrified the fascist aggressors, are the remote descendants of the rocket which were manufactured in the Petersburg plant under Konstantinov's direction. The combat action of the rockets had affirmed the truthfulness of the conclusions drawn by Konstantinov about the role of the rocket weapon.

Zasyadko and Konstantinov were not the only Russian workers who tried to develop a combat rocket.

The pupils of Konstantinov - artillery officers, who participated in the work of the Petersburg rocket establishment, later supervised the action of rocket batteries in the units of the Russian army.

Separate units of the army were conducting experiments with rockets; Colonel Kostyrko and Colonel Vnukov were manufacturing rockets even before the Konstantinov time.

The successor of Konstantinov, General V.V. Mechaev, who supervised the manufacturing and use of combat rockets, was also conducting experiments in the development of new sample rocket projectiles.

Among the persons who participated in the rocket business was a well-known inventor, Alexander Il'ich Shpakovskiy.

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K.I.Kons'antinov greatly influenced the activity of A.I.Shpakovskiy, with whom he became well acquainted still in the 50's.

Since 1878, Shpakovskiy worked as a technician at the Kronshtadt mine workshops. His work consisted of the development of rocket compounds, including a special compound for the propulsion of mines (Bibl.2).

Russian rockets were successfully employed in combat operations.

Permissions were asked by many regimental commanders to form rocket batteries in their units.

Rocket artillery successfully acted during the siege of Ak-Mecheti (1853), and in the battle at Kyuryuk Dara (1854) (Fig.8).

Every year, rockets were transported to the Orenburg corps for training purposes and for reserve.

During the siege of Silistriya (1854), rocket batteries were covering combat-engineer operations, conducted firing at the enemy's fortifications, cavalry and infantry and opposed the enemy offenses.

Count Gorchakov witnesses that "rockets can be of great assistance at sieges of fortifications", and requested that 2000 rockets be sent to him in addition to the 2000 received by him previously).

In 1855, the rocket unit of Blockbuster Usov, participated in the battle for the Kars fortress. It carried on successful combats against artillery and fired at enemy fortifications. Its action, in the opinion of the command, was "always highly successful".

In 1860, rocket batteries were participating in the battle for Pishpek. The reports contain some indications of effective action of rocket batteries. "Hence, we can be definitely convinced that there are many cases when the rockets are irreplaceable and that this weapon is a powerful auxiliary means for artillery".

In 1861-1863, rocket batteries were effectively employed in battles in rocky regions of the Caucasus: "battery and separate divisions repeatedly and efficiently

participated in marches and offensives and were many times congratulated for opening the way".



Fig.8. Russian Rocket Artillery in Combat

These successes of the combat rocket were possible only as a result of the works of the creators of the Russian rocket weapon.

To the end of the past century, black powder combat rockets have lost their value and were removed from the armament of the army in connection with the progress in artillery technique (rifled bores and smokeless powder). The last data indicating the use of rockets in the Russian army is related to the period of the Russo-Turkish War in 1877-1878. The period before the First World War, inclusively, shows only separate episodic cases of the use of powder rockets and of research in

this field. In 1912, N.M. Pomortsev experimented with rockets attached with ring stabilizers. These experiments were continued at the Aerodynamic Institute at Kuchino in 1916. During these experiments, the measures of various characteristics of rockets were carried out by means of ballistic and other devices. Tests of recoilless reaction cannons and rockets, rotating in flight to maintain stability, were also conducted.

During the First World War, rockets were used against captive aerostats for illumination, signaling and also for armament of airplanes and infantry in close combats.

It is necessary to mention, however, that this use of an accidental character and a combat rocket intended for the accomplishment of various missions, did not exist. Thus, the captive of artillery, I.N. Zhukov related that the soldiers of his regiment often used illumination rockets in place of combat ones; instead of the illumination compound, the rocket was filled with hand grenades.

To introduce the combat power rocket in the army as armament, its combat-technical characteristics should have been considerably improved. First of all, it was necessary to study the powder compounds for rockets and to carry out a research and constructive work on development, tests and employment of the new sample of a combat rocket.

Russian engineers accomplished outstanding results in this direction. Vladimir Andreevich and Nicolay Ivanovich Tikhomirov were the creators of a new powder rocket.

The appearance of a combat rocket using smokeless powder designated a new period in the development of rocket armament. This rocket was created in the Soviet Union and the priority of its creation belongs to the Soviet rocket technique (Bibl. 3).

The first rocket experiments were accomplished by the artillery of the Brest-Litovsk fortress. During the First World War, Artem'ev substituted the charge of the three-inch rocket (illuminating stars) by seven parachute torches of an alluminum compound. The time of illumination increased to 1½ minutes. After the

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beginning of the war, the rocket was reconstructed by Artem'ev and demonstrated before the Staff of the Southern front. The rocket was recognized as inefficient on the basis of the overmassiveness of the launching stand, long wooden tail and mainly because of the inconvenient method of ignition. The rocket compound was ignited by a candle fastened to the end of a long wooden pole, called "pal'nic". The preparations for the operation were long and the process of ignition itself was inefficient under conditions of trench and maneuver wars. It was accepted only for use in shore and permanent fortification defense.

Artem'ev started a research with the purpose of creating combat rockets, using smokeless powder because the black powder rockets were inconvenient in the field wars and because the experiments with different compounds of the three-inch organic illuminating rockets in the direction of range increase were unsatisfactory.

Engineer Tikhomirov also worked on the same problem. In 1920, they began to work together. They organized a mechanical workshop and started the research on the utilization of smokeless pyrolin powders in rockets, used in armament. But the powders existing at the time proved to be unsuitable for rockets.

Artem'ev, in 1924, offered to manufacture a heavy-walled, smokeless powder block with non-volatile solvent, the first sample of which was manufactured in the same year. The first demolition blocks were pressed thin (about 25 m) because it had been suspected that the manufacturing of the thick demolition blocks would be unsuccessful and it will be necessary to glue them together by means of acetone lacquer. Further, it became possible to produce blocks up to 100 m long.

For long-distance flights, Artem'ev and Tikhomirov proposed to fire a rocket mortar in such a way that it would continue the flight under the influence of reaction force.

In 1924, the firing of an organic, three-inch illumination rocket from a mortar was carried out. The rocket was modernized: the long wooden tail was replaced with a shorter metal tail; the cap with illuminating stars was substituted by a

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corps of organic 76 m artillery shell; near the nozzle on the external surface of the rocket chamber, were mounted wings - stabilizers.

The first two or three rockets, when fired from a mortar at the angle of 45-50° traveled a crooked, zig-zag trajectory. When the center of gravity was transferred closer to the head, all rockets followed a correct trajectory. The firing range increased.

The rocket firing from a mortar eliminated the use of the existing high launching stand; the ignition was accomplished from the mortar charge, which was ignited by conventional means - by the stroke of a trigger on the capsule of a brass cartridge of the mine charge.

In 1925-1926, Tikhomirov conducted stand experiments with powder blocks 24 m in diameter. The tests of blocks of bigger diameter were conducted later. They were necessary for the development of a rocket projectile.

The first independent rocket ballistic laboratory for studying the laws of burning large powder blocks was established. The manufacturing of experimental powder blocks was set in 1927. The test results of the large blocks were positive and after the material parts were manufactured and a series of preliminary tests accomplished. On March 3, 1928, Artem'ev launched the rocket which was constructed by him and the mine with smokeless powder charge constructed by Tikhomirov.

"That was the first rocket powered by smokeless powder", says V.A.Artem'ev. There is no data which indicates the manufacturing of rocket projectiles (mines) working on smokeless powder in foreign armies before they were manufactured in our country, and the priority belongs to the Soviet Union. The creation of this smokeless powder rocket can be considered as a foundation for the constructive development of rocket projectiles for "Katyusha", which were of a tremendous help to our Soviet Army during the Great Patriotic War.

After the first rocket mine was launched, the most serious attention was directed to the development of the rocket armament.

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The presence of the heavy mortar material parts of the firing of rocket mines was depriving the mechanism of mobility, but in the condition of the field war, maneuverability is one of the advantages of operating with rocket projectiles. Therefore, the development of rocket projectiles, not employing mortars for firing rockets, but working only on the reaction principles of propulsion, was organized.

N.I.Tikhomirov died in 1930, but the enterprise started by us at that time, was in the dependable hands of young engineers.

The works of Tikhomirov, B.S.Petropavlovskiy, laureate of the Stalin premium, V.A.Artem'ev, A.G.Kostikov and other Soviet engineers greatly influenced the development of the combat rocket technology.

Soviet constructors were honored with high government rewards for the development of excellent samples of rocket armament.

Rocket armament has found an extensive employment in air forces. Aviation rocket weapon, first employed by our armies, still in the battles at Khalkin-Gol, was developed by Soviet constructors and was accepted as an armament in air forces. A group of constructors, which developed aviation armament, was given high status of laureates of the Stalin prize.

5. Combat Powder Rockets

In the middle of the past century, the armament of an army included various types of combat rockets such as: grenade, case shots, signal, illuminating and incendiary. There existed rockets for plunging fire (similar to the modern mortars and howitzers) and for long range firing (similar to modern cannons).

Russian rockets were manufactured of three calibres (for the calibre was accepted the diameter of the rocket chamber or, as it was called, cartridge case): 5.5, 12.5 and 10 cm.

Here is the description of a rocket of Konstantinov's time:

"A rocket is a projectile which consists of an iron tube-cartridge filled

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with a rocket compound, with a furrow, bored along the axis, of a certain size. A combat or incendiary shell is attached at one end of the cartridge and an iron bottom cover at the other with an opening, in which, along the axis of the rocket, is screwed in a wooden tail.

There were rockets of the combat type with grenades and case shots and incendiary and demotion rockets (Fig.9).

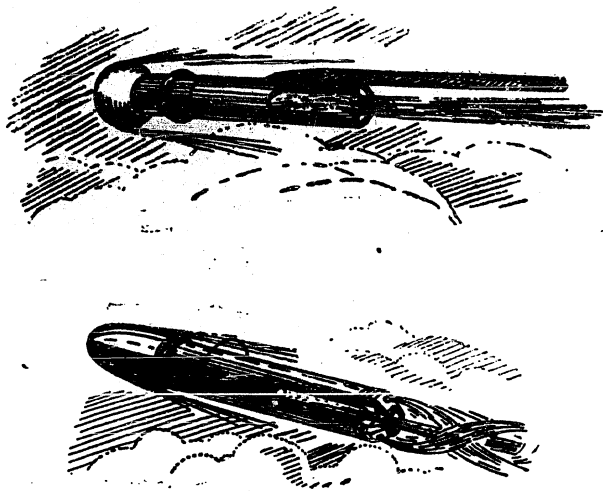


Fig.9. Combat Rockets of the 19th Century

Cartridges were made of sheet iron. A projectile with an explosive charge, shots or illumination compound was installed in the upper part of the cartridge. The bottom part was enclosed by a cover with openings for the exit of powder gases.

To make the rockets stable in flight, they were equipped with a tail or set in rotation in a way similar to the modern projectiles.

The rockets were launched from a very simple stand. It was either a tube or

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1 a trough mounted on a tripod. The stand could be turned up and down. The stand was
2 turned right or left by changing the position of its legs as is done in the case
3 of a support for a photo apparatus.

4 The charge was ignited by means of a fuse.

5 Konstantinov had offered a percussion tube, consisting of a long iron tube
6 with a device for the ignition of a percussion cap in it. The ignition would occur
7 at the stroke of a trigger on the percussion cap and the fire would be transformed
8 to the propulsive charge of the rocket.

9 That was the working principle of the combat rocket of the past century, which
10 was the predecessor of modern rocket projectiles.

11 Almost a century passed. A combat rocket underwent many transformations. In
12 a modern powder projectile, a steel rocket chamber is used instead of an iron
13 cartridge.

14 Instead of a long wooden tail (its length sometimes reached 5 times the length
15 of the cartridge), we see tail feathering - stabilizers. There are also rotating,
16 i.e. turboaction, projectiles.

17 It is interesting to mention that in the past, attempts to build rockets with
18 wings similar to the modern stabilizers, were made. We have already mentioned
19 rotating rockets.

20 Here again, we meet some old ideas which are realized on a new technical
21 basis.

22 Now the rocket chamber has a nozzle for ejecting gases in place of a bottom
23 plate with "glasses".

24 Here we give an old method of ignition:

25 "At the command "stand" number 2 shakes off the fuse, and all other personnel
26 take two steps away from the stand, as a protective measure against damage from
27 fire and sparks issued by the burning rocket, and also as protection against an
28 explosion of the rocket which is in the case of number 1, which releases it in

the stand. At the command "fire", number 2 applies the fuse to the fuel line".*

Modern powder rockets have ignition of the electrical type.

The construction of rocket projectiles of certain types, which were used in the past war, is shown in Fig.4 and 10. In Fig.4 is shown a feathered projectile, in Fig10 - rotating projectiles with upper and lower motor attachment. Each projectile consists of a body with an explosive charge, which contains also an ignitor, a

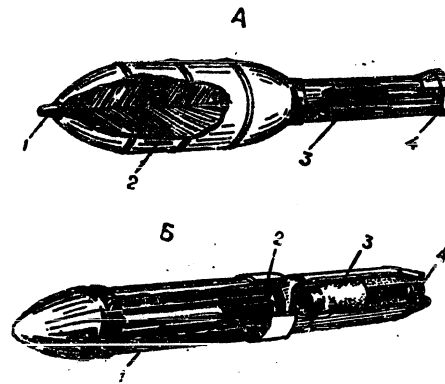


Fig.10. Rocket Projectiles

A - Rotating, with lower attachment of the motor; 1 - Ignitor; 2 - Combat part with an explosive charge. 3 - Rocket chamber with powder blocks; 4 - Nozzles.
B - Rotating with an upper attachment of the motor. 1 - Rocket chamber with powder blocks; 2 - Nozzles; 3 - Combat part with explosives charge; 4 - Fuse.

chamber with powder blocks and a nozzle (or several nozzles). The corps of non-rotating projectiles are attached with stabilizers.

*Artillery men attending cannons were given numbers. This was also accepted for rocket batteries.

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Multibarreled rocket installations permitting firing of 60 or more rockets are used in place of launchers reminiscent of the photo apparatus holder.

But now, as well as before, the specific peculiarity of a rocket stand or "launcher", as it is called, is simplicity and light weight.

These launching devices are tubes, guiding rails or carcass mechanisms. We can find them in mortars, automachines, armour transports and landing barges and under the airplane wings, and in antiaircraft rocket installations.

There also exist single-barrel rocket devices which include anti-tank guns firing rockets and mines.

Anti-tank rocket guns have been employed against tanks at short distances; rocket guns were also employed in street fights.

A powder combat rocket has appeared on the combat fields again, and as a hundred years before, was accepted as an armament.

6. Rocket Artillery

How was the powder rocket, the oldest and at the same time the youngest combat weapon, employed before and how is it employed now?

It is the oldest because it has existed as long as powder, which enabled the creation of firearms.

Rockets were employed in many wars. Russian rocket arms fill many glorious pages in the history of our native artillery.

Konstantinov wrote about combat rockets: "In our opinion, the combat rocket is a weapon which is as important to our ground forces as to the Navy". And now, when combat rockets have appeared again, his words are fully fulfilled.

That is the youngest weapon because it was revised during the past war and became a modern combat weapon. Powder mines and projectiles found a wide application in artillery (Fig.11).*

*This and other parts of the book use actual materials published in periodical literature and report publications.

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6 Rocket mortars installed in automachines secured a great maneuverability in
8 units of such kind.

10 Tanks also were armed with rocket devices. Aiming was accomplished by means
12 of mechanisms of the conventional type used in tanks. The guidance of these devices
14 could be accomplished from the inside of the tank. Tankmen could fire both salvos
16 and single shots. On the accomplishment of the firing, the rocket installation
18 could be disposed and the tank could turn to the offensive.

20 Tubes or rail guidings were mounted under the wings of airplanes and rocket
22 "cannons" of this kind were attacking ground objectives from the air.

24 Rocket artillery was widely employed during navy operations, especially in
26 landings.

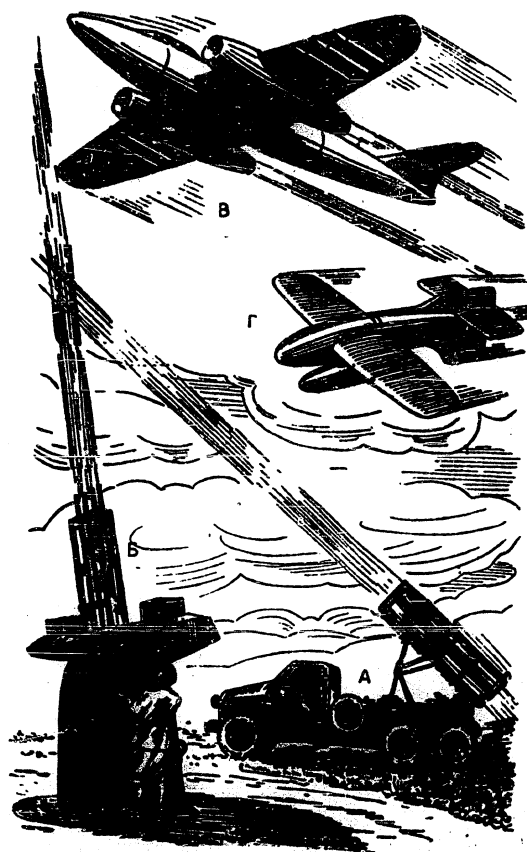
28 Usually, before the landing is undertaken, war ships support the landing
30 forces, destroying the enemy with their fire. To create a fire of great density
32 and to demolish the enemy that is well fortified entirely, it would be necessary to
34 concentrate tens of ships against every kilometer of the shoreline. This is com-
36 plicated in many ways. Powder rockets have solved this problem. By accumulating
38 a great amount of launching devices on ships and landing barges, the armada directs
40 concentrated rocket fire upon the fortification of the enemy.

42 Rocket artillery can be successfully employed against submarines also. A
44 small patrol ship could fire in two - three salvos a hundred rocket projectiles,
46 some of which would reach the discovered enemy submarine and destroy it.

48 Bombs with powder boosters and aerial rocket torpedoes with powder motors,
50 which were employed against visible targets at short distances, such as sea ships,
52 were also disposed from airplanes.

54 A hydrobomb with a rocket powder motor, reminiscent of a torpedo, was intended
56 for surprising enemy ships. It was disposed from a bomber and at the moment of
58 water contact, the circuit of the ignition candle which ignited the solid fuel of
60 the rocket, would close. The depth of the bomb course was regulated by special

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instruments and the prescribed direction was accomplished by gyroscope.

Powder rocket motors were installed in certain aerial torpedoes launched from airplanes and also intended for attacking sea ships (Fig.12). A pilot, after the torpedo was fired toward a target, could guide its movement by radio; a bright tail of fire made the guidance easier. The other guided projectile with a powder motor, which was also released from an airplane carrier, could be guided on a previously prescribed course, preserving the direction given to it and later correcting the guidance by means of radar. Rockets were also employed in antiaircraft defense. Antiaircraft guided projectiles had wings and some of them had boosters, which could be separated after the fuel was exhausted. The construction of one projectile of a similar kind is shown in Fig.12. The projectile has three pairs of wings and steering wheels attached to the front part of the body. The booster has two

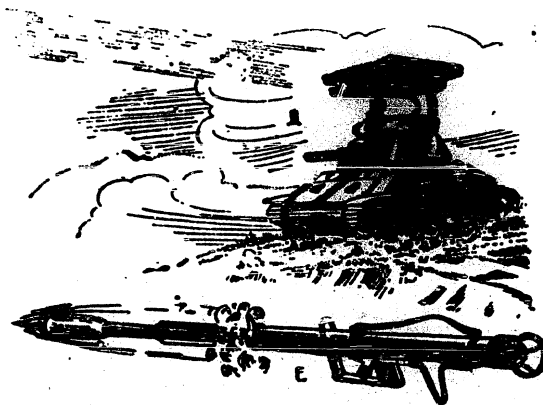


Fig.11. Rocket Weapons

A - Rocket mortar; B - Antiaircraft rocket installation; V - Aviation rocket projectiles situated under airplane wings; G - Aerial rocket torpedo; D - Multi-barrel rocket installation on a tank; E - Anti-tank rocket gun.

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01 pairs of wings. The projectile was launched from a special trestle and aimed toward
 02 the target, i.e. an airplane, by means of ground radar. Signals were received by a
 03 radioinstallation, then, intensified and transferred to the elevators and rudders.

04 Another guided projectile was intended against dive bombers. Its propulsive
 05 device consisted of four powder rockets. Its form and guiding devices were simi-
 06 lar to an airplane. It had rudders, elevators and flaps attached to the wings. This
 07 device contributed to the maneuverability of the mechanism. Signals, which guided
 08 the action of flap and rudder motors, were transmitted by radio. The projectile
 09 was launched from a launching stand whereupon to increase the speed of the run,
 10 several booster rockets were used and later disposed of.

11 Experiments concerning the combat employment of guided, solid-fuel rocket pro-
 12 jectiles against bomber units, acting at the time of war, were carried out. Similar
 13 projectiles were attached with wings or convertible stabilizers which could be ex-
 14 tended in flight. There were various systems of guidance and control (tele-
 15 guidance, radio transmission by radio or cables, target finders securing automatic
 16 aiming during the last phase of the offensive) and conventional distance fuses
 17 acting at a certain distance from an enemy airplane.

18 Complex powder rockets (Fig.12) could be employed in long range firing.

19 As we see, a powder rocket has found an extensive and varied employment in
 20 artillery.

21 7. Peaceful Uses of Powder Rockets

22 With the appearance of rifled bores in artillery and also smokeless powder,
 23 the use of war rockets started to diminish and to the end of the 19th century com-
 24 pletely ceased.

25 All countries, one after another started to denounce the rocket artillery.

26 The last rocket batteries in the Russian army were liquidated in 1897.

27 But the development of rocket weapons had pushed inventors to the idea of

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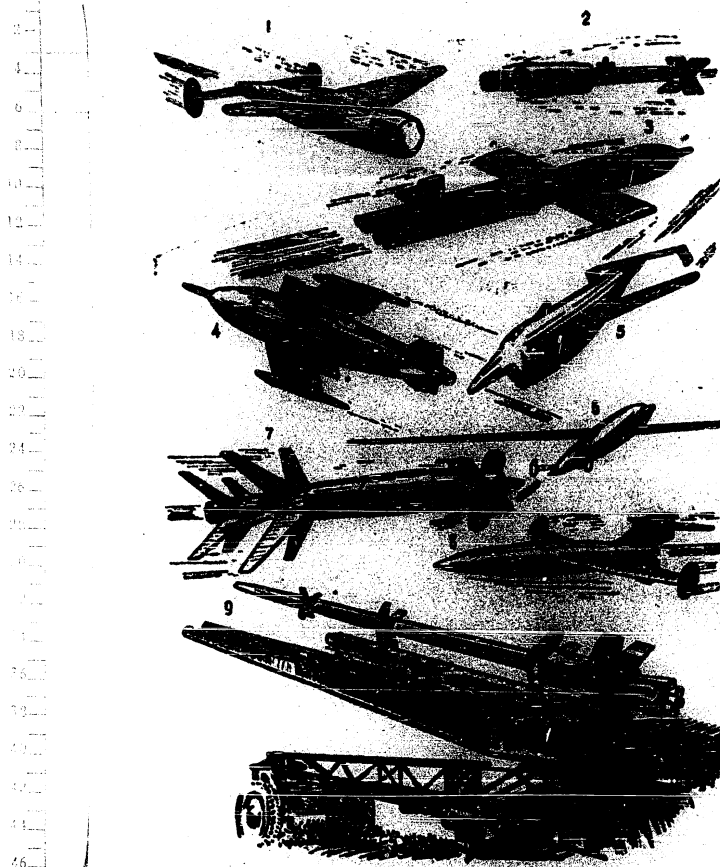


Fig.12. Rocket Guided Projectiles and Solid Fuel Rockets

- 1 - A guided projectile intended for surprising ground targets, launched from an airplane. 2 - Antiaircraft rocket projectile with radar fuse; 3 - Antiaircraft projectile, radio guided; 4 - and 5 - Guided missiles for surprising aerial targets, launched from airplanes; 6 - Guided missiles for acting from airplane against sea targets; 7 - Guided antiaircraft projectile (with a booster); 8 - Guided projectile for aerodynamic research; 9 - Multi-stage long range rocket installed in launching stand.

using rockets as a propulsive power for flights. High technical level of rocketry in Russia greatly contributed to the solution of this problem.

In fact, in the middle of the past century, there existed pockets capable of propelling heavy projectiles for a distance of several kilometers.

Konstantinov died in 1871, and ten years later, in Petersburg, not far away from the Winter Palace, the sound of an exploding hand grenade, which killed Alexander II, was heard.

This grenade was made by a Petersburg student, narodovolets, N.I. Kibal'chich.

The history of one of the first projects of rocket flying apparatus is closely connected with the name of Kibal'chich. After the assassination of Alexander II, while being confined to a prison, Nikolay Kibal'chich, up to the very day of execution was continuing work on the development of a flying projectile, propelled by the power of slow burning propellents.

The motor, consisting of one or several chambers with gas pullets, and possessing freedom of movement, was mounted on a platform. The direction of flight was influenced by the inclinations of the motor installed in a rotating position. The motor could have several chambers. Small cylinders of compressed powder - powder candles were fed into the chamber by automatic mechanisms. The regulation of exhaust was accomplished by the adjustment of the fuel consumption.

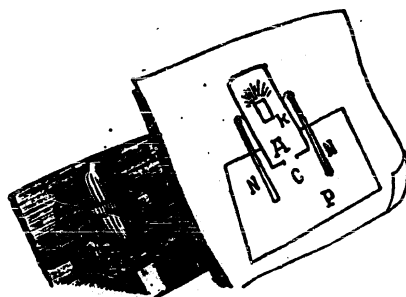
Kibal'chich presented a schematic description of the mechanism, specified the stabilization methods and the ways of guidance, and also indicated the possibility of the employment of wings.

He correctly understood the principle of rocket propulsion and was the first to introduce the idea of rocket employment for a manned flight.

In the end of the 19th century, there were offered a number of, mostly unapplicable, projects of flying mechanism powered by rockets.

That was the period of search. Some authors of such projects proposed to use the propulsive force of powder, gases; the others - vapor, water, air, alcohol

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46 Kibal'chich, Nikolay Ivanovich (1854-1881). Born in the Chernigov region.
 48 Finished 3 years in the Institute for Railroad Engineers; from there he transferred
 himself to the Medical and Surgical. Was arrested for participating in student
 50 organizations and for possessing illegal literature.
 52 After his release, he studied the properties of propellents. He produced
 mines for the assassination of Alexander II, which occurred on March 1, 1881. For
 54 the participation in the attempt on his life, was sentenced to be executed. While
 being in prison, he designed a rocket power manned flying mechanism with a powder
 56 motor. The Kibal'chich mechanism, principally, was suitable not only for flying
 but also for interplanetary travels.

vapor, oxygen and hydrogen.

But the only practical realized motor then and in the beginning of the 20th century was a powder rocket motor.

The following example clearly illustrates this period of rocket development.

The author of one book regarding rockets, which was published 25 years ago, relates numerous projects of rocket flying mechanisms, including a project of a dirigible with a powder rocket motor. On the accomplishment of the description of projects, he concludes that the mentioned inventions are interesting as ideas, but impractical. The motion was uneven and consequently damaging for the construction of the dirigible. Rocket regulation and replacement was accomplished manually and that was tiresome and unreliable. It was doubtful whether the dirigible could lift the required amount of rockets and, finally, the possibility of explosion was not eliminated.

There were many projects of powder rocket flying mechanisms which could hardly lift their own weight, but, without any doubt, would explode.

However, many interesting ideas can be discovered upon the careful investigation of these projects.

For example, it has been offered to use a rocket for photographing terrestrial surface.

Later, it was offered to use rockets in airplanes for assisted braking before landing.

The Russian inventory, Charkavskiy, proposed "to assist the airplane take-off by utilizing the energy of powder charge explosion".

At the present time, aviation extensively employs starting powder rockets for assisted take-offs of aircrafts. It is especially convenient during mountain flights and under combat conditions.

Rocket boosters can be used for lifting gliders into the air.

A powder rocket booster consists of a metal balloon with a powder charge and

a nozzle. An ignitor with an electric lighting device is screwed into the wall of the balloon. Upon the accomplishment of the take-off, the booster is disposed off (Fig.13).

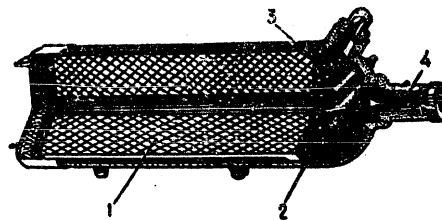


Fig.13. Solid-fuel Rocket Booster

1 - Powder charge; 2 - Diaphragm; 3 - Ignitor; 4 - Nozzle attached with a protective cover

It is necessary to mention that only rocket flying mechanisms were designed. In the end of the 20's, some attempts were made to employ powder rockets in automobiles, trolleys, sleds, motorcycles, planners and also bicycles.

These experiments proved that a powder rocket motor is suitable only for projectiles. Its operation is comparable to a prolonged discharge, however, manned flight in a projectile is impossible.

The flights were usually unsuccessful. In 1928, pilot Stammer was almost burned while flying in a glider with a powder rocket. Rocket motor trolleys and cars were exploding frequently.

Eventually, the combat designation of rockets became evident. But, if a man cannot use rockets for flying, it does not mean that destruction is their only intention.

Previously, we have mentioned life-saving rockets invented by Konstantinov. Powder life-saving rockets were used to transfer cables to ships requiring help

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close to the shore.

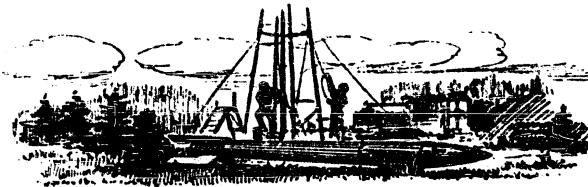
By means of powder rockets, cargos and mail can be transported for a small distance.

We have mentioned that a powder fuel motor is practically possible. At the end of the war, an experimental projectile was built, with a motor intended for aerodynamical research (Fig.12). It is in many ways similar to an aero-torpedo and becomes a small pilotless aircraft, guided by means of an automatic pilot.

And finally, as many centuries ago, a powder rocket was used as a fine decoration during holidays and carnivals. Soaring through the night skies of darkened Moscow and scattered in the air as thousands of multi-colored lights, firework rockets were announcing glorious victories of the Soviet Army during the salutes of the Great Patriotic War, and are decorating public holidays and gatherings with the most beautiful garlands of firework lights, blossoming over the Soviet cities during the peaceful days of creative work.



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THIRD STORY

THE SECOND BIRTH OF THE ROCKET

1. New Rocket Fuel

Previously we have analyzed a powder rocket motor which is remarkable by the fact that it is also a fuel tank. But powder is not the only rocket fuel. It is irreplaceable in artillery because there the combustion of short duration is required.

In 1903, Konstantin Eduardovich Tsiolkovskiy designed a rocket powered by a new fluid fuel.

To master the new rocket-fuel voluminous work has been required.

And when it was accomplished, the second birth of the rocket virtually occurred. Fluid-fuel rockets began to be employed as armament in airplanes; long range rockets have left far behind the records established by super long range artillery, acting in the period of the First World War. Research rockets were climbing several times higher than the high altitude research instruments - sounding balloons; and finally, later, rocket motor aircrafts, airplane-rockets were also introduced.

Let us thoroughly analyze the fluid-rocket fuel. That will help us to understand the construction and working principle of a liquid-fuel motor.

But before we do that, we have to undertake a short excursion into chemistry.

It is well known that the process of burning is combination of elements of the

fuel with oxygen. The chemical reaction called burning consists of combining the molecules of the burning substance with oxygen molecules. As a result of this reaction heat and new substances, i.e. products of combustion are formed.

The participants of the reaction are two. One of them is fuel and the other is oxidizer (oxygen).

The fuel and oxidizer, as we have seen, are the components of a solid fuel-powder. There they are connected in such a way that each particle consists of a mixture of fuel and oxidizer, differently speaking - the propellant.

Also the liquid fuel which is used now in rockets consists, certainly, of fuel and oxidizer; they are not combined, but are stored separately and become intermixed only in the combustion chamber.

Such fuel is called two-component fuel; it usually consists of two parts, assuming that they are separate, independent parts.

Rocket fuel has to satisfy a line of qualifications. First of all, the fuel must be highly efficient, i.e. heat producing. The higher is its efficiency and gas production, the higher is jet velocity and consequently the altitude and range of the flight.

To serve as a coolant for heated parts of the motor, the fuel must be capable of absorbing as much heat as possible, i.e. to possess a high thermal capacity. Along with that it must not decompose or precipitate under the influence of high temperatures.

The fuel and oxidizer must be well suitable for dispersing and intermixing in the combustion chamber. Therefore they must possess small adhesiveness which facilitates its spraying and passing through the jets.

High inflammability and complete combustion of short duration are important qualities of a fuel.

It should be remembered that the fuel and oxidizer together represent a very powerful explosive substance. Accumulation of propellents in the motor and delayed

ignition may result in explosion. Several tons of fuel pass through the motor of a large rocket in one minute. Therefore, the combustion must be complete, short and efficient.

The success of the starting operation secures the faultless work of the motor. Therefore, the fuel must be highly inflammable. It is even better when the fuel and oxidizer are self-ignited when intermixing in the combustion chamber. But not all fuels have this characteristic. Sometimes, to secure self-ignition, an addition of special compounds to the fuel is required.

Soviet scientists were the first to propose the idea of self-ignition.

It is desirable for a fuel to have a high specific gravity. From two fuels which produce equal jet velocity, the one which has higher density is more efficient for it has smaller volume and requires lighter containers.

During preservation, transportation and general handling of the fuel, the personnel must not be placed under danger of explosion or poisoning, and materials and mechanisms must be protected against corrosion.

The fuel itself must be as stable as possible. It must maintain to keep its properties during preservation or when subjected to heat or cold. Finally, it must be accessible, i.e. produced in sufficient quantities and moderately priced.

Let us analyze fuels and oxidizers used in rocket motors.

One of the most interesting fuels is hydrogen. In combination with the liquid oxygen it can be very efficient and highly gas producing. Especially important is the fact that in the process of converting from atomic hydrogen into molecular it produces an enormous amount of heat. But hydrogen even in liquid state has a low density, it means that the containers for the required amount of fuel must be large. Besides that, liquid gases evaporate easily and demand special double walled storage. Because of a comparatively low boiling point and considerable difficulties connected with the use of pure hydrogen it became necessary to adapt for this purpose some hydrogen rich substances.

Methyl and ethyl alcohols are the most adapted fuels. This fuel was first experimented with in the Soviet Union. Later it was used by the Germans.

Benzene and other complex compounds are also accepted fuels. Aviation kerosene is used for jet-reaction motors.

The use of the following fuels will be possible after a preliminary research: acetylene, ethylene, turpentine and phosphoric carbon bisulfide solutions.

Liquid oxygen, nitric acid and hydrogen peroxide are accepted as oxidizers. The idea of using liquid oxygen as an oxidizer was introduced by K.E.Tsiolkovskiy in 1903. It is, of course, the best existing oxidizer. In liquid state it is cheap, accessible, poisonless, has sufficient specific weight and this fact, as we saw on example of hydrogen is a significant one. A number of engineers in the Soviet Union were studying and experimenting with rockets powered by liquid oxygen.

It is true that the employment of oxygen for cooling is complicated. When the liquid oxygen is used, then, very often, the other part of the propellant, the fuel, accepts the position of coolant.

The property of liquid oxygen to evaporating easily can be regarded as a disadvantage.

Previously we have mentioned a word "coolant". What is a coolant and why is it needed?

In the process of combustion of fuel there is produced a considerable amount of heat; The temperature in the combustion chamber of a liquid rocket exceeds 3000 C. Such high temperature demands cooling of heated motor parts, such as a combustion chamber and a nozzle. The most convenient way of cooling is by means of fuel components. By absorbing the heat produced by the motor, the fuel becomes heated before entering the combustion chamber.

Liquid fuel rockets use liquid oxygen as an oxidizer.

The employment of liquid gases, however, is very important. Therefore, it became necessary to find a substitute for liquid oxygen.

Hydrogen peroxide was offered as one of such substances. Many difficulties were encountered on the way of its use. The experiments with hydrogen peroxide were followed by several explosions. The investigations of these explosions show that they were caused by contacting hydrogen peroxide with certain substances which cause its disintegration, and if it is violent, it will result in an explosion. Even when hydrogen peroxide is completely isolated from copper and other substances which produce the explosion, it cannot serve as a good oxidizer for it is unstable and inefficient.

Provided hydrogen peroxide is added some catalysts such as sodium or potassium permanganate, then the liberation of vapors and oxygen continues to be produced. Their mixture, vapor/gas can be used in turbines, rotating pumps which feed the fuel into the rocket motors.

Carbon hydrates with nitrate acids or tetranitromethan (a compound consisting of carbon with nitrogen and oxygen) as oxidizer is a good propellant.

Nitrogen acid, the use of which was first introduced in our country, is widely accepted in rocket propulsive systems. However, it has serious disadvantages: dangerous handling, the ability to absorb air moisture (hygroscopy) and ability to affect material but its production is well organized by the chemical industry.

Tetranitromethan is a much better oxidizer at times, and will find extensive employment in rocket motors.

Instead of a regular oxygen, liquid, i.e. three atomic oxygen has been offered.

The possibility of the use of ozone was first offered by Y.V.Kondratyuk. Ozone is more efficient than the regular oxygen and possesses higher specific weight. It is, however, unstable and highly explosive.

The chemistry of rocket fuels, perhaps, will find the way of making ozone more stable. It can be used as a good oxidizer independently and in mixture with liquid oxygen. The accomplishment of that will result in better efficiency of thermal processes taking place in a motor.

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3 Besides the oxidization, i.e. combination with oxygen, the reaction of combin-
4 ation with halogens which are accompanied by a release of a large amount of heat
5 can also be used.

6 The most active of them and highly poisonous is fluorine. Its capability to
7 react with all chemical substances handicaps its use. Some fluorine compounds can
8 be used as oxidizers.

9 Chloric acid, perhaps, will be used as an oxidizer in self-igniting fuels.

10 Propellents, one part of which, oxidizer or fuel, is solid, can also be used
11 in rockets.

12 Solid fuel and oxidizer are placed in the combustion chamber where the liquid
13 part of the propellant is injected during the motor operation.

14 Thus, the motor, as in the case of a powder rocket, is also a fuel tank and
15 that, consequently, simplifies the construction. But the injection of the liquid
16 oxidizer therefore, becomes more complicated: the fuel burns out, the conditions
17 inside the combustion chamber change and to maintain an even combustion a careful
18 adjustment of the oxygen intake becomes necessary. Soviet engineers were the first
19 to use solid fuels in combination with liquid oxidizers.

20 As solid fuels, silicon compounds possessing high thermal efficiency, are of
21 a special heating value.

22 Motor details manufactured from pure silicon and carborundum can be burned
23 in the combustion chamber after their usefulness has expired.

24 Soviet inventors F.A.Tsander and independently from him, Yu.V.Kondratyuk,
25 have proposed to utilize metals as rocket propellents.

26 To increase the efficiency of the fuel, Kondratyuk proposed to add metals
27 to the propellents. But Tsander suggested to burn in the combustion chamber the
28 used parts of the rocket which were previously melted or crashed. The following
29 metals are acceptable for this purpose: beryllium, boron, aluminum, magnesium and
30 lithium.

Tsander's proposition opens a wide perspective before rocket technology.

At the present time, a research in the field of metal fuels is being conducted. Metals can be used not only in melted or dispersed condition, but also as ingredients of colloid solutions or in combination with other substances. Metalized colloid fuels with beryllium, for example, are capable to substitute high efficient hydrogen-ozone mixture. Metals when burning, create temperatures higher than those of the liquid fuels and it requires new materials for rocket motors and new methods of cooling.

Another type of fuel which will be important in the future is the so-called one-component fuel which consists of fuel and oxidizer simultaneously. Powder is a sample of solid one-component fuel. Fuel of this kind explodes easily, i.e. decomposes. To avoid this danger, an addition of special ingredients is required.

The employment of liquid one-component fuel would simplify the fuel injection into the rocket. The research on the development of liquid-powder motors was first undertaken in the USSR.

To the one-component fuels belong also fuels which release heat in the process of combining atoms into molecules. Hydrogen, for example, in the flame of the Petrov ark, can be transformed into atomic form by splitting molecules into atoms. When combining again and acquiring the molecular form, hydrogen releases a tremendous amount of heat. The most hardmelting metals, including tungsten, melt at temperature of 4000°C, are used in atomic-hydrogen welding. But the atomic hydrogen is unstable and this handicaps its use as a fuel. Atomic energy, which we shall describe later, opens a wide field of application for hydrogen, the most effective fuel in the Rocketry.

2. From Powder to the Atomic Energy

Tremendous jet velocities, many times exceeding the velocity developed when burning thermochemical fuels, can be produced by the atomic energy, i.e. the heat energy released when the decomposition of the nucleus of atoms occurs.

Previously we have mentioned the main requirements presented to rocket fuels.

The fuel must be compact and along with this, must secure the maximum jet velocity from the combustion chamber.

We have described advantages and disadvantages of various fuels, solid and liquid.

By means of molecular reactions it is very hard to develop jet velocities exceeding 4000 m per second. Perhaps, it would be possible to increase somehow this figure by means of metal fuels. Practically these values will be even smaller taking into account the losses inevitable for every motor.

Jet velocities much higher than ones developed by now existing burning mixtures, can be reached by heating hydrogen with energy released from decomposing the nucleus of atoms. Specific exhaust (c.f. Section 3) and jet velocity, in this case, are higher than those produced by modern fuels.

But we have to remember that the peculiarities of atomic energy will require many changes in the construction of rockets. For example, it is known that the release of intra-atomic energy is accompanied by extremely damaging radioactive radiations and heat which cannot only melt metals, but evaporate them. Many studies are required to solve the problem of protecting the future passengers and instruments from destructive radiation, and mechanisms and motors from the heat developed by the atomic installations.

The use of atomic energy opens wide perspectives before Rocketry. And there is no doubt that these difficulties, standing in the way of atomic progress, will be conquered.

After the First World War, when the development of rocket motors was just beginning, the absence of necessary heat resistant materials was the principle hinderance in this progress. It is worth mentioning that the use of liquid-fuels, along with the opening of new horizons before the rockets, has developed new difficulties also. Virtually the rocket motor is made of propellents, for metals

are combustible under certain conditions. High temperature in the motor and the presence of oxidizer hinder continuous burning. The life expectancy of the first motors was very short. Only before the Second World War it became possible to solve this difficult problem and dependably operating motors were created. Cooling became the next principle problem to solve.

These problems of materials and cooling are, of course, in very close connection.

Now we know how to protect the rocket motor from the action of high temperatures. Employment of heat resistant materials and different methods of cooling secure dependable operation of motors.

When the use of atomic energy is mastered then the problem of materials will become actual. Science and technology, armed with the experience of the past, will solve this problem in the future also.

3. The Construction of Rocket Liquid-fuel Motors

Now, when we have the knowledge of liquid fuels employed in rocket technology, we can analyze also the peculiarities of liquid-fuel rocket motors.

Because the liquid propellant consists of fuel and an oxidizer, which are intermixed immediately before the combustion, then the combustion chamber cannot simultaneously serve as a fuel tank as it was observed in the case of powder rocket. It must be stored separately.

Because the tanks and the combustion chamber are separated, the fuel must be injected into the chamber. For feeding it, special devices, for example, pumps, are required. That makes the motor more complicated and also adds to it a line of significant advantages over the powder type engines.

The exhaust in liquid-fuel rocket motors can be regulated by adjusting the consumption of fuel. In the case of the powder motor, such regulations are difficult. Here the exhaust and the velocity can be changed only by using powder

charges of various form and by varying their places in the chamber.

The operation of the liquid motor can be stopped by closing the fuel entrance into the combustion chamber. By regulating the fuel and oxidizer intake it is possible to control the motor operation and to vary its exhaust.

Thus, the propulsive installation must have the following main parts: the combustion chamber with a nozzle, fuel tanks, injection devices, spraying, fuel intermixing and ignition systems (if the fuel is not spontaneously ignited) and also guiding mechanisms.

The liquid fuel rocket motor is a motor of multi action. It can be shot off during the flight and started again. That property is used in aviation. An interceptor with such a motor can alternate the motor flight with gliding and consequently increase the flight time.

Fuel and oxidizer enter the chamber through the sprayer at a certain ratio: less fuel and more oxidizer.

To provide atomizing and intermixing, the oxidizer and fuel are injected under a pressure whereupon the stream of propellents encounter each other, or the intermixing can occur in a partly evaporated condition. Ignition is reached by means of electrically ignited powder cartridge or by means of chemical ignitors.

For example, it can be done by adding into the chamber of substances which become spontaneously ignited when coming into contact with one of the components.

During the period of starting, an accumulation of the fuel mixture and consequently the danger of explosion can occur in the motor. To eliminate this, fuel and oxidizer are not fed at the same time, but one after another, or are fed first in such a ratio which secures a safe operation and only after a normal process of burning has been established, the fuel feed proceeds normally.

The fuel which was injected in the chamber before the burning began, must be heated.

When the fuel is ignited and a reliable flame is established, the ignition can

be shot off. Every new portion of fuel which enters the chamber is ignited by contacting hot gases contained in the chamber.

The combustion in the engine occurs under considerably high pressure, but not of several hundreds atmosphere, as in a powder motor, but of several tens atmospheres.

There are two methods of feeding the fuel into the combustion chamber (Fig. 14).

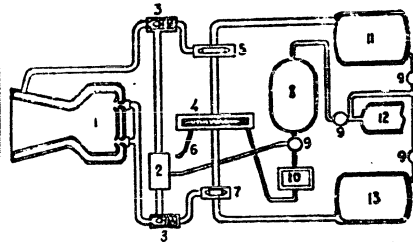
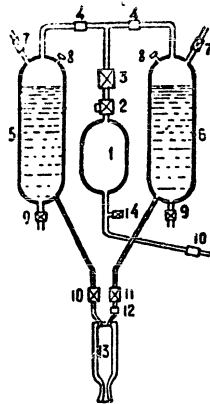


Fig. 14. A Layout of a Liquid-fuel Rocket Engine.

A - With balloon feed; 1 - Balloon with compressed gas; 2 - High pressure compressed gas valve; 3 - Pressure regulator; 4 - Control valves; 5 - Oxidizer tank; 6 - Fuel tank; 7 - Ventilator valves; 8 - Injector sleeves; 9 - Injector valves; 10 - Intake valve of compressed gas balloon; 11 - Feeding valves; 12 - Jet nozzle; 13 - Combustion Chamber; 14 - Ejecting valve;

B - With pump feed; 1 - Combustion chamber; 2 - Fuel valve regulator; 3 - Valves; 4 - Turbine; 5 - Fuel tank; 6 - Gas exit from turbine; 7 - Oxidizer pump; 8 - Hydrogen peroxide tank; 9 - Faucets; 10 - Vapor gas generator; 11 - Fuel tank; 12 - Condensed gas which is fed into the fuel tank to increase the pressure outside the pumps and for injecting hydrogen peroxide into generator; 13 - Oxidizer tank.

The fuel components can be fed under the pressure of compressed air or some gases (mostly nitrogen), contained in the balloon, i.e. pressure accumulator. The compressed gas pushes the fuel out of tanks, not reacting, of course, with the fuel chemically. Therefore, gases similar to nitrogen, which do not react with

the fuel, must be chosen.

Feeding under the pressure of hot gases, created during the process of powder burning in a separate chamber, i.e. the powder accumulator of pressure, can be used besides the feeding under the pressure of cold compressed air. In the accumulator the constant pressure of gases can be maintained.

This method of feeding is very simple and the engine with a balloon or accumulator type of feeding, like a powder engine, does not have any moving parts.

This simplicity, however, causes complications.

Because the feeding occurs under the pressure, fuel tanks must be very durable and consequently heavy.

The engines with balloon feeding were used in rocket projectiles, torpedoes, start rockets. However, the possibility of their employment in long range or high altitude rockets is not excluded.

The engine of this kind also requires cooling. In one engine with balloon-type of feeding, used in antiaircraft rocket projectiles, the oxidizer, nitric acid, which cooled the combustion chamber and nozzle, was injected into space between double walls.

The fuel was fed under the pressure of compressed air several tens atmospheres.

When a continuous work, strong exhaust and large quantities of fuel are required, then other method of feeding, pump-system feeding, is used. Pumps which inject fuel and oxidizer into the chamber are mounted between the fuel tanks and the combustion chamber.

A special turbine or any other motor sets the pumps in motion. The turbine uses hot gases created in the auxiliary chamber. The chamber contains hydrogen peroxide, the dissociation of which produces gases for the turbine action.

Whereupon the tanks are subjected to a very small superfluous pressure, they, therefore can have thin walls and lighter weight.

Such method is employed in engines of long-range rockets and rocket airplanes.

It demands a complex equipment as high speed powerful turbines, pumps, systems of reliably working valves and switches. The guidance becomes more complicated too.

Constancy of fuel mixture, feeding pressure and second consumption is regulated by devices which are mounted on the fuel path, from the pump or tank, (in case of balloon feed) to the combustion chamber.

The construction of a rocket engine which uses liquid fuel, including the system of fuel injection, cooling and regulation, which must operate reliably and exactly, is pretty complicated.

The process occurring in a liquid fuel rocket aviation motor is also complicated. Feeding the fuel into the combustion chamber, cooling the walls of the chamber and the nozzle, a simultaneous evaporation of fuel and oxidizer, the process of their combustion in the chamber, gaseous efflux at high temperature and at high velocity - all these and many other phenomena still require further investigation.

As a sample, let us analyze the working principle of one of the liquid fuel rocket engines intended for large rockets which were employed during the Second World War.

The propulsive mechanism of the rocket consists of a combustion chamber, a nozzle, fuel tanks, aggregates for fuel feed (steam-gas generator, turbine, fuel pumps) and guiding system, which directs starting operation and shoots off the engine. In Fig.15 are shown the main view of the engine and its details.

The engine, working on alcohol diluted with water (fuel) and liquid oxygen, consumes 25 kg of propellant in a minute. The combustion chamber, which is made of special steel, has a pear shape. The combustion chamber is attached by an oblong widening funnel - the nozzle.

The combustion chamber and the nozzle have double walls, and into the space between them alcohol coolant is injected. In the head part of the chamber are situated valve nests which are presented in Fig.15. Each such nest has one big oxygen valve, surrounded by small alcohol valves. Oxygen is injected by a pump

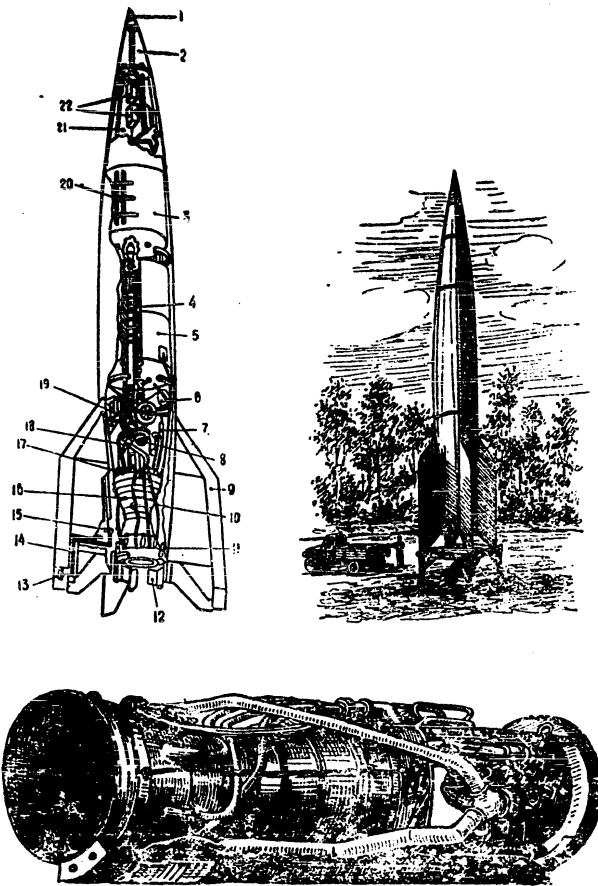


Fig.15. Modern Long-range Liquid-fuel Rocket and Its Motor

- A - General view of the rocket; 1 - Nasal part with ignitor; 2 - Combat part;
 3 - Alcohol tank; 4 - Alcohol supply line to the motor; 5 - Liquid Oxygen tank;
 6 - Hydrogen peroxide tank; 7 - Calcium permanganate tank (gas-generator is situ-
 ated in rear); 8 - Oxygen distributor; 9 - Stabilizers; 10 - Alcohol supply line
 for cooling; 11 - Servo-motors; 12 - Gas rudders; 13 - Aerial rudders; 14 - Chain
 transmission to aerial rudders; 15 - Electromotor; 16 - Combustion chamber and

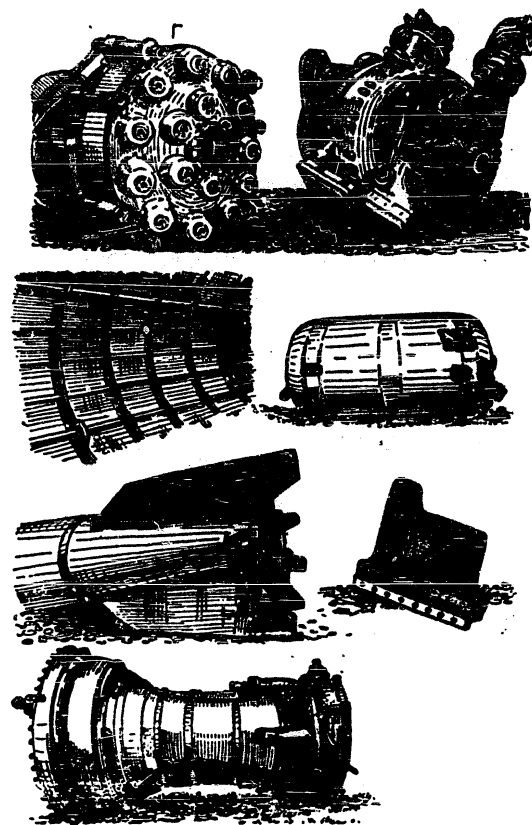


Fig.15. Modern Long-range Liquid-fuel Rocket and Its Motor

nozzle; 17 - Forechambers; 18 - Alcohol feeding system; 19 - Turbo-pump aggregate;
 20 - Carcase; 21 - Guiding section; 22 - Radioequipment; A - Rocket installed on a
 launching stand; V - General view of the motor; G - Head part of the combustion
 chamber with jet-nests; D - Turbo-pumps; E - Covering; Sh - Fuel tank; Z - Tail
 part of the rocket with stabilizers; E - Graphite rudder; K - Nozzle.

under the pressure immediately to the valves, whereas alcohol enters the clearance between the walls of the nozzle. A small part of it passes through the small openings into the nozzle, cooling its internal walls. This considerably reduces the temperature of the walls.

The rest of the alcohol enters the cooling jacket of the chamber, which is formed by its double walls and only later reaches the valves.

To eliminate the distortion produced by heating, the jacket is constructed furnished with waves which compensate the thermal expansion of the walls.

Before the combustion the fuel and oxidizer are intermixed in the precombustion chamber especially mounted in the front part - in the head of the motor.

Ignition is accompanied by means of pyrofuse ignited by electric power. Later, after the stable point of burning was established, the fuel in the chamber becomes spontaneously ignited and continues to burn.

Alcohol and oxygen are injected into the engine by two pumps operated by a turbine. The turbine uses a steam and gas mixture which is produced in the pre-combustion chamber. In this chamber occurs the dissociation of hydrogen under the influence of calcium permanganate resulting in hot gases, which rotate the turbine. The pressure in the motor chamber reaches about 16 atmospheres. The combustion products are ejected at a velocity equal to 2000 m per second. The engine develops an exhaust of 25,000 kg and operates for 60 seconds.

In Fig.16 is shown an aviation liquid rocket engine. The fuel feed is accomplished by a turbine device. In rocket projectiles the motors are not operated by man directly but by manipulating a lever in the cockpit, a pilot regulates the fuel injection. Exhaust can vary in fairly wide limits (from 200 to 1700 kg).

The engine works on self-igniting fuel. The combustion chamber is cooled by the fuel circulating in a cooling jacket.

The weight of this motor was 160 kg and could propel an aircraft at a speed up to 900 km per hour.

Let us analyze now the peculiarities of liquid fuel rockets.

The rocket engine is a thermal engine. It converts the energy contained in fuels into energy of gaseous motion.

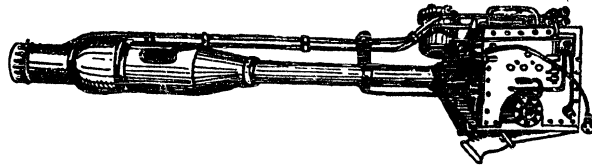


Fig.16. Aviation Liquid Rocket Engine

The efficiency of an engine shows how complete and economical the produced work is.

The efficiency of an engine characterizes the completeness of a thermal engine. The smaller are the losses of energy in the engine, the higher is its efficiency. The losses of heat energy in the rocket engine occur both during the fuel burning and also during the gaseous efflux.

Because the process of burning is not ideal, a certain part of the fuel remains unburned and is wasted. Complicated processes which occur during the efflux of gases consume a certain part of heat energy. Heat is also lost while the engine itself becomes heated.

Engine efficiency is a ratio of the heat converted into useful work to the entire amount of heat produced during the combustion.

Thus, the efficiency shows how large are all these and various other losses in the engine. The efficiency of a rocket engine can be characterized by a magnitude similar to that of other thermal engines.

It also helps to evaluate the amount of fuel energy used for propelling aircrafts, in this case, rockets.

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Finally, it is possible to evaluate the general losses as in the engine itself, so during the flight. Efficiencies related to these two cases, increase when the velocity of the rocket reaches the velocity of the exhaust gases.

That is why the rocket engines are efficient only at high speeds, close to the velocities of exhaust. Even when a rocket automobile moves at a record speed of about 400 km per hour, its efficiency was not more than 0.03. Only 3% of the fuel energy was efficiently spent. The efficiency of a rocket engine increases with the increase in speed. Artillery and aviation where the velocities of motion are high, are the main fields for rocket motor application.

The engines also can be compared by their specific weight. This weight is not determined by the weight of a unity of volume, as it is accepted in physics, but by weight corresponding to one unity of exhaust.

A specific weight of a liquid rocket engine is only 50 g per one kg of exhaust, sometimes more, but never higher than 150 g.

Differently speaking, a rocket liquid-fuel engine is capable to develop a high exhaust by a small weight, for example, the weight of a rocket engine which developed exhaust of 25 tons was equal to 1 ton. Possessing a small weight and consequently small size, it developed a tremendous power which, in flight at maximum speed, was equal to 500,000 hp.

That is a great advantage of a rocket engine.

We can imagine this better when we realize that to every kg of exhaust developed by an aviation engine corresponds 0.2-5 kg of its weight. Therefore, an engine, which is capable of developing 25 tons exhaust must weigh up to 50 tons.

The exhaust of a rocket engine increases with the increase in altitude, because the pressure outside the nozzle decreases.

At 10 km altitude the exhaust of the rocket engine increases on 12% more, than at the ground; at altitude of 20 km - on 15%.

The highest jet velocity can be developed by a rocket engine in a vacuum space.

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Konstantin Eduardovich Tsiolkovskiy was the first to indicate that the rocket engine can be used in interplanetary ships.

Previously we have mentioned a specific weight of a rocket engine. Beside it, there also exists a term "specific exhaust". That is exhaust which corresponds to one kg of fuel consumed in 1 second.

Specific exhaust of a modern engine is 200-250 kg for a kg of fuel per second. Specific exhaust is closely connected with efficiency. It shows the grade of motor perfection, and evaluates the completeness of fuel consumption.

Knowing the specific exhaust and exhaust which should be developed by an engine, we can determine the second consumption of the fuel.

For example, if the specific exhaust is 200 kg for a kg of fuel in one second, and the exhaust developed by it is equal to 25 tons, then the fuel consumption in one second will be equal to 125 kg of fuel.

At the present time, the rockets using liquid fuels are employed for establishing high speeds. Rockets which use such engines develop velocities several times exceeding the velocity of sound. The duration of operation is not long - it is in limits of one minute. Aviation rocket motors, which were used during the war in interceptors had the period of operation only about 4 minutes. In the future, the time of motor operation, of course, will be increased.

The constructors of rocket motors at the war time were mainly pursuing the purpose of reliability of motor operation, as the most important in the war time. The energetic resources of fuel were not completely exhausted. The development of high altitude rockets, the increase in altitude and lifting capacity demand improvements of propulsive mechanisms and employment of more efficient fuels. Rocket motors will be widely used in high speed aviation also.

They will be progressing along the way indicated by Tsiolkovskiy - from the rocket aircraft to an interplanetary vessel.

4. Motor Operation

What kind of processes occur in a liquid-fuel rocket motor?

The fuel entered the combustion chamber. The chamber has two zones. The space which accomodates the spray burner can be counted as the first zone. Here, the fuel and oxidizer are atomized, intermixed, heated and, finally, evaporated. Temperature here is considerably low.

The second zone is the zone of combustion. Here, at the moment of burning, the molecules of oxidizer-oxygen or any other chemical substance containing oxygen, are combining with molecules of the fuel-alcohol, benzene, etc. Here occurs a complicated chemical process as the result of which gaseous products of burning are first created and later ejected from the combustion chamber through the nozzle.

As soon as heated, intermixed and atomized, fuel and oxidizer enter the second zone, the temperature begins to rise sharply. The combustion temperature reaches 3000° and even higher.

All these transitions of oxidizer and the fuel from one zone to the other inside of the combustion chamber and all processes occurring there are almost of intangible duration.

So, for example, from the moment of ignition (or contact in case of self-ignited fuels) to the moment of explosion it takes not more than 2-3 hundredths of a second. The fuel remains in the chamber only several hundredths or thousandths of a second.

The pressure in the chamber at the moment of combustion is approximately 15-20 atmospheres, whereas inside of the chamber it changes insignificantly for the velocity of gas motion in the chamber changes inconsiderably.

From the combustion chamber gases enter the nozzle, where the pressure drops abruptly, but the velocity considerably increases.

To increase the velocity of a gas stream moving at speed lower than the velocity of sound, the canal must become narrower. On the other hand, if the canal becomes wider, the velocity of gas motion decreases. Let us recall the flow of a

river: where there the river bed becomes narrower, water flows faster, and there where it widens, the water slows its motion down.

But to what extent can the velocity in a narrowing canal be increased?

It is evident that the highest velocity possible to develop when gas is moving in a narrowing down canal is equal to the velocity of sound traveling in this gas at given circumstances - temperature, pressure, density.

Velocities higher than the velocity of sound, or as it is called "sound barrier", could not be reached before, in the process of many experiments, a nozzle was manufactured, which had a special shape permitting the development of supersonic speeds.

If in the narrowest place of the nozzle, it is called, "critical section", velocity which is equal to the speed of sound is established, then in the extensible part of the nozzle the velocity will not decrease, as in case of sonic speeds, but, on the contrary increases.

That is why jet velocity developed by modern rocket engines with extensible nozzles reach supersonic velocities up to 2000-2500 m per second, and in the future, when the efficient types of fuels will be developed, it will be even higher.

Tsiolkovskiy was the first to recognize the advantages of the increased pressure inside of the combustion chamber, indicating that it produces higher jet velocities.

However, it results in a considerable increase in weight of the constructions and in the necessity of using cooling systems, because the temperature of gases and the heat flow toward the walls of the chamber increase.

Multi-chamber engines, which similarly to rockets consist of several separate motors are being developed. This type of construction permits such regulation of exhaust that it places the entire installation under the most efficient condition for operation. On the other hand, the research on new materials for combustion chambers and nozzles is going forward. The processes accompanying the motor

operation and new fuels are being analyzed.

The stage of experimenting with the rocket engine inside the laboratory walls had been accomplished and it established itself along the line of other thermal engines.

5. Materials and Tests

The combustion chamber and the nozzle must be manufactured from special materials and provided with cooling systems to satisfy the exceptionally difficult work conditions.

It is sufficient to mention that the maximum temperature in the motor rises above 3000° and the pressure reaches tens of atmospheres. The amount of heat released relative to the unity of volume of the combustion chamber is thousands of times that released by the furnace of a steam boiler.

Parts of liquid-fuel rocket motors which are subjected to thermal effects are made of special steel and some other heat-resistant alloys.

Sometimes, in motors intended for operation of short duration and not equipped with cooling system, the nozzle is made from copper - the metal which conducts heat well. Inside it is covered with a protective layer of chromium, and also with graphite or any other heat resistant material.

The engines with operations of long duration require cooling systems besides heavy steel and copper walls.

The cooling of the combustion chamber and nozzle is very important.

Only propellents which boiling point is high can be used as coolants. Otherwise the propellant begins to evaporate before it reaches the combustion chamber and upsets the normal process of burning. Overheating of separate parts of the combustion chamber may cause its disruption.

The efficiency of cooling was proved by the fact that the nozzle and other parts of the motor, the post-work state of which was thoroughly investigated, were

heated only to 600° C.

In the case of airplanes, where the operation of the power producing installations must be of long duration, this fact indicates complications on the way of exploitation.

For manufacturing air-reaction aviation motors, which operate longer than rocket engines, metallurgists have created special alloys. The temperature here is lower, the combustion products in air-reaction motors are diluted with air, the combustion chamber is cooled by pure air.

An additional thorough research in the field of materials for manufacturing rocket engines is required.

They (materials) must combine high heat conductive properties with extreme durability under high temperatures. The materials used at the present do not possess these qualities; heat-resistant steel has poor heat conduction qualities, and copper, on the contrary, is poor heat-resistant material.

The future employment of atomic energy in rocket engines means several times the increase in temperatures and that, in its turn, poses a challenge to metallurgists, manufacturing rocket materials and to engineers developing the cooling system for the rocket engines.

It must be indicated, that liquid oxidizer can chemically affect the materials of their production, for example, fuel pumps. This factor cannot be neglected, for it limits the operation of oxidizer pumps.

In recent years there was conducted an intensive scientific research on liquid rocket fuels, thermal processes, construction of engines and elements of power installations, such as feeding systems, cooling, etc. As a result, aircraft motors of different constructions were designed. Their characteristics were considerably improved. It is sufficient to mention that, for example, during one quarter century time period the value of specific weight decreases more than 30 times.

Very significant data had been received from tests conducted on stands and in

flight intended to investigate the operation of new mechanisms as well as these which are manufactured in series. The stand tests are conducted in especially equipped chambers.

A test stand consists of several compartments: fire compartment where the engine is mounted, fuel tank compartment, compartment for guidance and observation, for instruments and all purpose compartment (Fig.17).

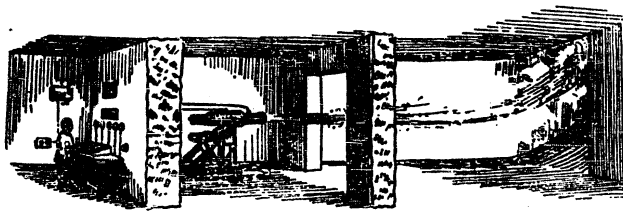


Fig.17. Tests of a Liquid-fuel Rocket Engine.

The operation of the engine is directed from a distance. The observations are carried on by means of instruments. Because the danger of explosion is not excluded, all instruments are covered with unbreakable glass and some special parts even with steel plates.

The purpose of these tests is to study the influence of different factors on the value of exhaust, such as the pressure in the combustion chamber, the ratio between the amount of fuel and oxidizer, their atomization and intermixing, thermal processes, heat exchange, cooling, etc. The entire engine and separate units of it are subjected to the study of this kind. There are many types and their cost is high. A thorough investigation of an engine which was described by us in detail above, would require several thousand tons of fuel. That is why there are very often conducted model tests of rocket motors.

Many different indications must be measured during the tests such as for: the

value of exhaust, fuel consumption, pressure and temperature in the combustion chamber, temperature of walls, combustion chamber and nozzle, jet velocity, etc. Measurements of two types are required during the tests: such corresponding to the well established cycles of operations when the measured values change only gradually, and such called "nonestablished cycles", i.e., the starting operation, the moment of cutoff of the motor, etc., when the measured values change intermittently.

The technique of these measurements is very complicated. Not mentioning all the details, let us describe one method used for determining the velocity and the temperature of gases ejected from the nozzle.

By means of a movie camera permitting to make 8000 pictures in a second, a stream of gases ejected from the nozzle was photographed; by projecting this film onto a screen at velocity of 25 pictures in one second it is possible to see the recorded phenomena 300 times delayed.

The temperature of the ejected gases can be determined by observing the change in color of small pieces of different metals placed in a flame. The recording of fast occurring phenomena (for example starting and cutoff of a motor) is accomplished by means of oscillographs - electronic instruments permitting observation of oscillatory processes.

The automatic method of measurement is employed extensively. The results produced by all instruments are photographed or recorded on a movie film, when experimenting on the ground and in the air during the test flights. Automatic recording machines are also employed. Rockets are usually studied at special proving grounds furnished with equipment intended for receiving radio signals and observing the flight.

6. Liquid-fuel Rockets

Now, when the working principle of a rocket motor is familiar to us, we can begin the construction of a liquid-fuel rocket.

A rocket has an oblong, streamlined body with a pointed head part, similar to the high speed projectiles.

The load is enclosed in the front part of the body: the explosive substance and ignitor - in a military rocket, instruments and parachute in a research stratospheric rocket, mail or a cargo in a mail or cargo rocket, a crew in a passenger rocket of the future.

The middle section of the body is occupied by fuel tanks, and in the rear section of the body is the motor.

The body is attached by stabilizers, and in the case of winged rockets - wings and feathering. The body consists of a frame and covering, manufactured from light metal alloys or from steel.

Rocket projectiles using liquid fuel, as it was proved by the experience of the past war, were extensively employed in antiaircraft artillery. In these projectiles the duration of motor operation is short and therefore the feeding by means of compressed air can be acceptable.

The starting operation was accomplished with the assist of boosters. Later the booster was separated, and the projectile to the end of the operation of the main motor could reach the supersonic velocity and approach the objective. The guidance was accomplished by means of radioinstruments. The projectiles were furnished with radar fuses. The altitude reached 15,000 m (Fig.18).

The Second World War established the beginning of the new weapon, adjacent with artillery and aviation, and which extensively employed the reaction motors.

From one side it is an aircraft: a flying apparatus with wings, motor, guidance system simplified to a certain extent, but without a pilot or crew. From the other side this is a projectile with an exploding charge and a fuse in the head part of the body. Not without a reason, one of these pilotless flying FAYu is still called "airplane-projectile".

Such guided projectiles were powered by powder, liquid-fluid with balloon

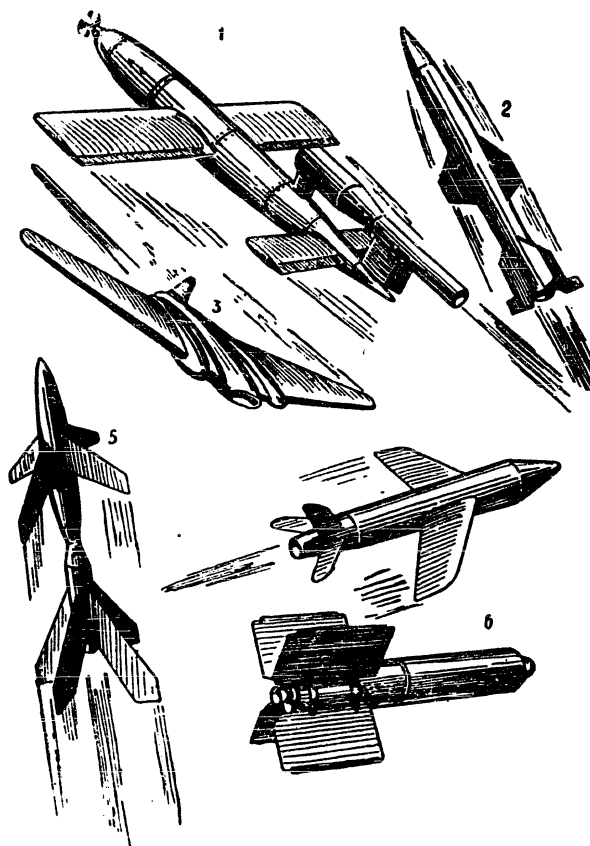


Fig.18. Guided Missiles with Rocket and Jet-reaction Motors and Liquid-fuel Rockets.

- 1 - Aircraft projectile with a pulsatory motor; 2 - Antiaircraft projectile with a radar fuse; 3 - Aircraft projectile with a gas-turbine motor; 4 - Experimental model of a rocket aircraft; 5 - Experimental guided missile (with a booster)
6 - Starting rocket for a guided missile.

type and pump feeding, and air-reaction engines.

The airplane-projectile was approximately 8 m long. Its cigar-shaped body contained the combat means consisting of approximately one ton of explosives and a system of fuses, instruments and mechanisms for guidance, fuel tanks, balloons with compressed air, and motors which rotate air propellers. The reaction motor was mounted above the body, wings sideways, approximately at the center of the fuselage, and the stabilizer with rudders in the tail part of the body (Fig.18).

This reaction motor was of the pulsatory type with a balloon system of feeding. Benzene was injected in the combustion chamber under the force of compressed air through the sprayer. The inlet of the motor was enclosed with a grate with plate-like slats, which open when the pressure of the oncoming air stream reaches a certain value. The combustible mixture explodes by contacting the overheated walls of the chamber, the pressure in the chamber increased closing the slats. The gases issued through the nozzle, the pressure inside the combustion chamber drops, the slats become open and the whole process begins again. This cycle repeats 50 times in one second.

To start an air-reaction engine, the air-plane projectile must possess certain initial velocity. Therefore, it can be accomplished with the help of catapults or from a flying airplane.

A catapult thrown projectile has an initial velocity equal up to 300 km per hour which is sufficient for setting a motor in operation. Automatic pilot was leading the small aircraft on the prescribed course. The covered distance was measured by a slat mounted on the nasal part of the body. When the required number of revolutions, which corresponds to the distance covered in the direction of the target, was gained, the aircraft-projectile was automatically changing to diving and exploded by impact.

There are different types of torpedoes intended for surprising aerial, ground and sea targets, with a radius of action from several km to several hundred km, and

with speeds ranging to supersonic. Their guidance systems include independent automatic guidance on prescribed course, like aircraft-projectile or a long-range rocket, and also guidance means of telemechanic devices, i.e. by means of radio signals. Guidance is accomplished automatically; a fuse operated by radar explodes the target when closing on it. Torpedoes, released from airplanes, can have a television equipment which permits the pilot of the leading airplane to see the target; the way is seen from the closing torpedo, and also radiocontrols which secure accurate aiming.

Because the speed of various torpedoes is considerably high, their aerodynamical forms resemble those of high speed aircrafts. They have arrow-shaped backward directed wings, oblonged fuselage, high lifted tail feathering; some of them are designed as "flying wing" (Fig.18). The aerial torpedoes can be powered by different types of motors such as: powder, liquid-fuel, jet-reaction, pulsatory, direct flow, gas-turbine type, and also by power complex plants. Rocket start boosters can also be used for imparting initial speed.

Aerial torpedoes were also used against the enemy ship when fighting on the sea.

By releasing and guiding a torpedo from a distance, an airplane is subjected to less danger of being surprised by the antiaircraft artillery of the enemy.

Aerial torpedoes have been employed against airplanes, too. They were attached to the fighters and released against the bomber units. The pilot of the fighter plane guided the torpedo by radio or by means of signals transmitted along the cables.

Aerial torpedoes and guided missiles, as we see, have found an extensive application in the military field. This type of weapon forms a special group of pilotless aviation including winged and wingless rockets, which are directed automatically in flight or from the ground by radio. Constructions, methods of starting, guidance and aiming of the pilotless flying mechanisms is different. Rocket

motors impart to torpedoes speeds ranging from under sound to supersonic range above 1000 km per hour as it can be found in some samples of projectiles, particularly of antiaircraft type.

Pilotless aviation can be used also for peaceful, research purposes.

High speed flights of guided automatic rocket airplane models can provide valuable data for constructors of high speed mechanisms and for scientists working in the field of aerodynamics. In Fig.18 is shown a design of one of such models intended for test flight at speeds in range of 1500 km per hour. The model has a balloon system feeding engine which begins to propel the aircraft after it was released from a flying airplane. Guidance is accomplished by means of automatic pilot which directs the aircraft in required horizontal course. A radiostation continuously transmits the data concerning the flight and motor operation to the ground; besides that the course of the model is also monitored by a ground radar station.

Similarly to the antiaircraft projectiles, the experimental rockets can have boosters which become separated after the takeoff.

Aircrafts with rocket engines possessing the highest speeds among all other types of flying mechanisms are the most important for the conducting of flying test at high speeds.

The rocket method of high altitude research started to be widely used during the recent years (See further, the fourth story).

Mail and cargoes will be transported for large distances by winged rockets, whereupon the further development of automatism and telemechanics will permit to utilize regular travel of pilotless rocket aircrafts.

Long-range rocket projectiles and research high altitude rockets can be powered by motors with turbo-pump system of feeding.

The rocket of this kind, but perhaps of larger size, will lift man into the stratosphere.

In the hands of militarists, the rocket is intended to be a weapon of destruction. We did not have and could not have FAU* - a medium of mass destruction of peaceful population. In our peaceloving country, the rocket will be the medium of great technical progress, it will open the road to stratosphere and interplanetary space.

Let us analyze in detail the construction of a modern liquid-fuel rocket which embodies in itself the progress of many fields of science and technology.

The body of a rocket consists of several compartments. The useful load is situated in the nasal compartment. It is followed by a compartment for guiding devices and radio instruments.

The flight of large rockets must be guided. To guide means to follow correctly the given course of direction.

In order to guide the flight the rocket is equipped with gas rudders which were designed by Tsiolkovskiy. The gas rudders are powered by small motors connected with automatic pilots (see page 101).

The autopilot has two gyroscopic systems. The axis of one gyroscope is directed along the axis of the rocket, and the other is perpendicular to it.

When the rocket deviates to one or the other side, the axis of gyroscopes maintain their positions in space. That is the main property of gyroscopes - fast oscillating gyrostat maintains the constant position of its axis. The frame of the gyroscope, which is connected with the body of the rocket, tilts and switches on the electric net. The obtained electric impulse is intensified in the net by an amplifier and acts upon the rudders, returning the rocket into the prescribed course.

On the contrary, if a change in the direction is required, then radio signals, received by the receiver and intensified by the amplifier, contact the net of the

*FAU is the first letter of the word Vrlgeltungswaffe, i.e. the weapon of retaliation, as long-range rockets and airplane-projectiles were called by the Fascists.

rudder motors which directs the rocket to the required course.

The radio equipment of the rocket includes also a transmitter which permits communication with the Earth by means of signals, which indicate its trajectory.

The readings received by means of instruments installed in rockets can also be transmitted to the ground by a radio transmitter. It also can be used for many other purposes. For example, investigations in determining the temperature of rocket covering during the flight were accomplished. For this purpose small discs of various metals with a certain melting point were installed in the covering; the discs were contacted with the electric net connected with a radio transmitter. When any of these discs melted, the transmitter would send a signal to the ground.

Radio guidance, however, is a method not completely dependable; its operation can be handicapped by interferences. There are several methods of rocket guidance along its course. There is, for example, an "astronavigational device" which determines the course by positions of certain stars. By comparing the observed position of the orienting star with a certain precalculated position, the device introduces the corrections for the course and constantly directs the flight.

Long-range rockets can be guided following a system of guidance with a precalculated program of course. Automatic mechanisms originate signals acting upon rudders which maintained the trajectory of the flight in the prescribed course. Such automatic guidance is not handicapped by interference.

Here, as in many fields of science and technology, the priority belongs to the Soviet people.

In 1940, first in the world tests of liquid fuel rocket motor designed by constructor L.S.Dushkin. This motor was installed in the glider of the S.P.Korolev construction. The tests were performed by a glider-pilot, V.P.Fedorov.

In May of 1942, an airplane with a liquid rocket motor, piloted by captain G.Ya.Bakhchivandzhi, climbed into the air.

To the end of the war the Germans also possessed airplanes of this kind.

We have mentioned before that the duration of the operation of the aviation rocket motor using fluid fuel was considerably short. The time of the flight of the interceptor-fighter with an operating motor was only several minutes long.

Interceptor-fighter with such a motor (Fig.19) was intended against bombers. After the take-off the shassi was disposed and the landing was accomplished by means of a ski extended before the landing. This aircraft possessed a high climbing capacity: it could reach an altitude of 12 km in 4 minutes and that is much faster than a fighter of the propellor type. The fuel consumption was very high, and the entire fuel resource, which amounted to one-half of the entire weight of the aircraft, was spent when operating continuously with maximum output in 4.5 minutes. Therefore, the range of the flight was short. The duration of air travel could be extended by gliding with shut-off motor.

During the War there were built and tested several types of similar rocket fighter-interceptors, and one of them, described by us above, was participating in combat actions. There exist several various designs and experimental constructions of rocket aircrafts.

For example, there was built and experimented with single-place fighter-interceptor closely resembling guided missile. A vertical take-off was accomplished from a special device consisting of a girder with guiding tracks. For some time after the take-off the interceptor could be guided by radio from the ground. Later while closing on the target, the guidance was accomplished by the pilot, who fired at the enemy plane with rocket projectiles or from guns. On accomplishment of firing, the pilot was bailed out on a parachute together with the seat. The motor landed separately also by a parachute. The required speed of the airplane was 1000 per hour.

There was also a design of a glider-interceptor intended for action against bombers from short distances and powered by the motor of the same type as that of the previously described interceptor. It was assumed that the amount of fuel would

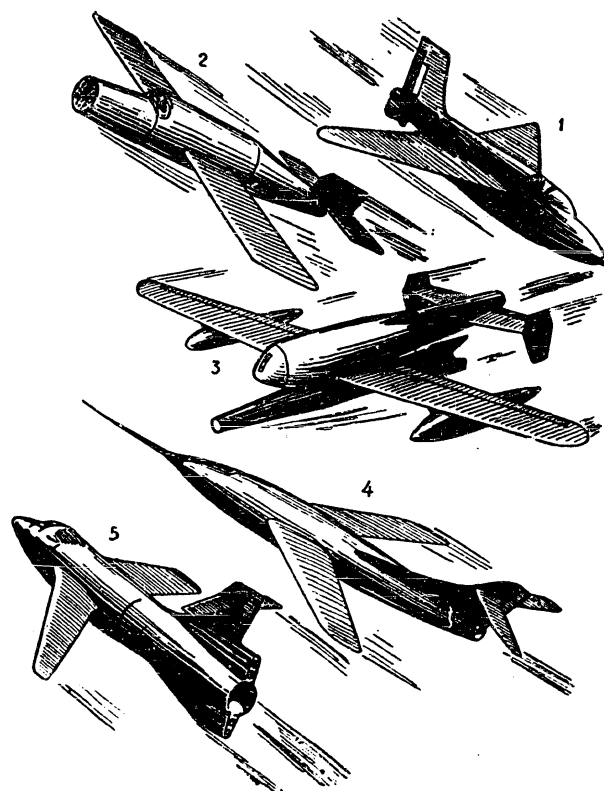


Fig.19. Rocket Aircrafts.

1 - Fighter plane; 2 - Fighter interceptor charged with a battery of rocket projectiles in nasal section; 3 - Fighter-glider with liquid fuel motor, a torpedo and two suspended tanks; 4 - Rocket airplane for experimenting at high speeds; 5 - Fighter with a gas-turbine and four rocket motors.

last for a 2 minute motor operation; the rest of the time it must glide with a shut-off motor (that is, from where the name of glider-inceptor has been received).

Such a fighter should have a strong armour and mechanism for shooting rocket projectiles and also for carrying torpedoes.

It is interesting to know that a pilot was requested by the constructor into a prone position which should ease the influence of acceleration. Because the fighter was not powered for independent take-off, it was supposed to be carried, similarly to a bomb, under the fuselage of a large bomber.

After releasing all rocket projectiles, it could glide and land at the closest air base from where it could be directed to combat again. A fighter-glider was also intended to attack ground objectives, enemy fortifications, tanks, sea ships. A pilot in the fighter-glider of this type should be properly protected by armour and would possess powerful rocket armament.

The aircraft of this kind, however, did not participate in combat actions.

During the post-war time, there were designed a series of rocket aircrafts which were described by the aviation press. Some of them had only rocket motors, the others a complete power installation consisting of jet reaction and auxiliary liquid fuel rocket engines (Fig.19).

The purpose of mentioning several designs of rocket aircrafts is intended for establishing the possibilities of using rocket motors in military aviation.

Now we have to mention rocket motors differently intended in aviation, i.e. rocket boosters operating on liquid fuel and which are widely employed.

A start-assisting liquid fuel aviation motor consists of a combustion chamber with a nozzle, three tanks - for fuel, oxidizer, and compressed air, and a distributing fuel feeding system.

The body of a booster is furnished with (Fig.20) several special devices for its attachment to the airplane; after the take-off, it can be disposed with a parachute. The guidance is accomplished from the pilot's cabin by the pilot who

connects the vent feeding compressed gas pushing the liquid fuel components into the combustion chamber. The fuel is self-ignited, and a jet stream is ejected through the nozzle mounted at a small angle to the longitudinal axis to the motor, in order to protect the body of the aircraft from the action of hot gases. The operation of the motor was approximately one-half a minute long with exhaust equal approximately to half a ton.

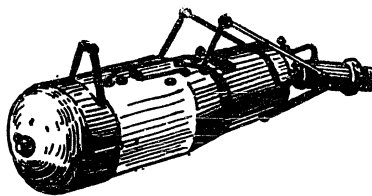


Fig.20. Liquid Rocket Booster.

The employment of boosters considerably reduced the run distance before the take-off.

Considering that a booster is used repeatedly (it lands by means of a parachute after the motor operation begins) the protection of the motor from damages must be accomplished in the direction of protecting the combustion chamber and the nozzle by means of fuel coolants.

The liquid fuel motor can be used as an auxiliary motor in an aircraft, in combination with other motors, as altitude booster or as a speed booster of short duration.

8. The Creators of Liquid Fuel Rockets

As it is wrong to describe the creation and development of aviation without mentioning the tremendous meaning of the works of the founder of aviation science Ye.Shukovskiy, so it is impossible to explain the operation of rockets

indicating the role of the creator of liquid fuel rocket propulsion - Constantin Eduardovitch Tsiolkoskiy.

Tsiolkovski produced a number of ideas exceptionally valuable for the development of rocketry.

All theoretical principles of Rocket propulsion and problems of designing liquid-fuel rockets were investigated by Tsiolkoskiy and have been employed in modern Rocketry since.

The Tsiolkovski works being the basis of the modern Rocketry also contain and represent the program of the future development of this field and provide the ideas which are daring and progressive.

These works show Tsiolkovski as an innovator as well as a representative of the foremost science which has "courage and determination to break down old traditions, standards, limits, when they become obsolete and anti-progressive". (I.Stalin).

Tsiolkovski revealed himself as an innovator in the field of rocket propulsion.

Powder has always been considered as the only efficient rocket fuel. The field of employment of a powder rocket was limited to the satisfaction of military needs.

Gun-powder, however, is not the most efficient rocket fuel. The introduction of a new liquid fuel has broadened the fields of rocket application.

Tsiolkovski developed an orderly theory of rocket propulsion and introduced a number of original ideas related to the rocket construction field.

He offered to use liquid fuel, and particularly liquid oxygen as an oxidizer, the use of carbohydrates, for example petroleum, as fuel, to cool the heated parts of the motor by means of liquid fuels, which later is directed into the combustion chamber.

A pump-liquid fuel feed system was designed by Tsiolkovski to solve the problem of liquid fuel injection. He offered to guide the flight in the space by means of graphite rudders which were mounted in the gas stream issuing from the

motor. Declinations in the position of "gas" rudders changing the direction of the gas jet would produce the change in the course of the rocket. He also proposed, in accordance with this purpose, to incline the engine on a small angle.

Tsiolkovskiy indicated the necessity of automatic guidance of rocket motor and direction of the course.

We must indicate that all these ideas of the founder of modern rocketry were realized in modern liquid-fuel rockets.

These rockets use a liquid fuel - liquid carbohydrates (for example - alcohol), and oxygen, which are injected by means of pumps. Before entering the combustion chamber, the fuel passes through the cooling jacket, formed by double walls of the chamber and the nozzle. Guidance is automatically accomplished by gas rudders (or by motor declination).

Therefore, it is clear that Tsiolkovskiy is the founder of liquid-fuel rockets.

The theory of rocket flight was first described by Tsiolkovskiy in his work "Investigation of Space by Means of Reaction Instruments" (1903).

Tsiolkovskiy proposed fuels suitable for use in rockets, and also considered the employment of atomic energy for the purpose of rocket propulsion.

He also is the author of a complex cosmic rocket design.

"A single rocket" - wrote he, "to develop a cosmic speed, must possess a great amount of fuel whereas a complex rocket gives a possibility of developing high cosmic velocities".

Maximum velocity of a single, one-stage rocket is limited by the fact that the motor output is directed on acceleration of the overall mass of the rocket, even when a part of it is empty and unnecessary.

In this respect, multi-stage rockets have a great advantage. Each stage is an independent rocket. After the fuel resources were used, it becomes separated from the body and its next stage is brought to the action. The last rocket, being the smallest, carries the pay load.



$$\frac{v}{v_1} = \ln\left(1 + \frac{m_2}{m_1}\right)$$

48 Tsiolkovskiy, Constantin Eduardovich (1857-1935); born in the village Ishevskiy,
 49 Ryasan' district. Being nine years old, suffered a heavy illness as a result of
 50 which he lost the ability to hear, almost completely. Being sixteen years old, he
 51 went to Moscow to acquire an education and there he began his self-education. In
 52 1879 he received his teacher's diploma after finishing special examinations. Taught
 53 first in Borovsk and later at Kaluga. From 1885 he began a serious study of air-
 54 navigation. In 1895 he designed the first aerodynamical tunnel in Russia. In the
 55 same year he designed an airplane. From 1895 he worked on a design of an all-metal
 56 dirigible. He started to study the reaction propulsion in 1883. His work "Invest-
 57 igation of Space by Means of Reaction Instruments", was published in 1903.
 58 Later he continued to work mostly in the field of rocketry, aviation and inter-
 59 planetary travels.

Complex rockets are accepted in modern combat rockets, pilotless aviation, and also are intended for research and flights at high altitudes.

Here is another example.

Tsiolkovskiy has proposed a design of a long nozzle (explosion tunnel). Rockets using liquid-fuel with a small combustion chamber and a long nozzle and also rockets with an "explosion tunnel" (where the combustion chamber was a nozzle at the same time) were built, just as suggested by him.

Tsiolkovskiy has indicated the path of the future development of rockets which will carry out the flight into interplanetary space.

The work started by Tsiolkovskiy was continued by Friedrich Arturovich Tsander, a well known scientist and talented engineer, who dedicated his entire life to the development of problems of rocket propulsion and interplanetary flights. As a result of Tsander's work, the problem of rocket flights ceased to be purely theoretical but acquired a practical and actual meaning.

All his scientific and experimental works were intended for accelerating the realization of interplanetary travels and overcoming difficulties existing in this direction. So, for example, the Tsander proposition concerning the utilization of rocket parts as rocket motor fuel considerably simplified the realization of cosmic flights.

In order to reduce the overall size of an interplanetary ship, the required amount of fuel and overload created at acceleration developed during rapid operation, Tsander proposed the design of a wing-rocket. The wings were used for traveling in the atmosphere of the earth, i.e. at take-off and landing. Because the weight of the rocket is considerably reduced to the end of the flight, the Tsander project indicated two systems of wings: large ones for take-off, which are later retracted and overmelted in a special kettle and later burned in the rocket motor; and small landing wings. He not only designed this cosmic ship, but also specified the most efficient alloys for its manufacturing: magnesium, aluminum and lithium, indicating

manufacturing and processing methods.

In 1930-1931 Tsender built motor rockets OR-1 and OR-2, which were successfully tested (Fig.21).

In motor OR-2, the fuel components are injected under the pressure of a neutral gas (nitrogen); the process of cooling is accomplished by means of oxygen directed into the cooling jacket from evaporators. The guidance of the mechanism was accomplished by regulating the feeding of the liquid oxygen and benzene.

In order to test motor OR-2, a glider was built and a row of calculations and investigations concerning rocket aircrafts was carried out.

Tsender died in 1933 without accomplishing the realization of his project. It was finished later by his students and followers.

Tsender studied and mathematically examined the flights of long-range rockets considering the most efficient courses of such flights.

New thermal cycles and methods of thermal computations for rocket motors were offered by Tsender and many theoretical questions concerning the operation of these motors.

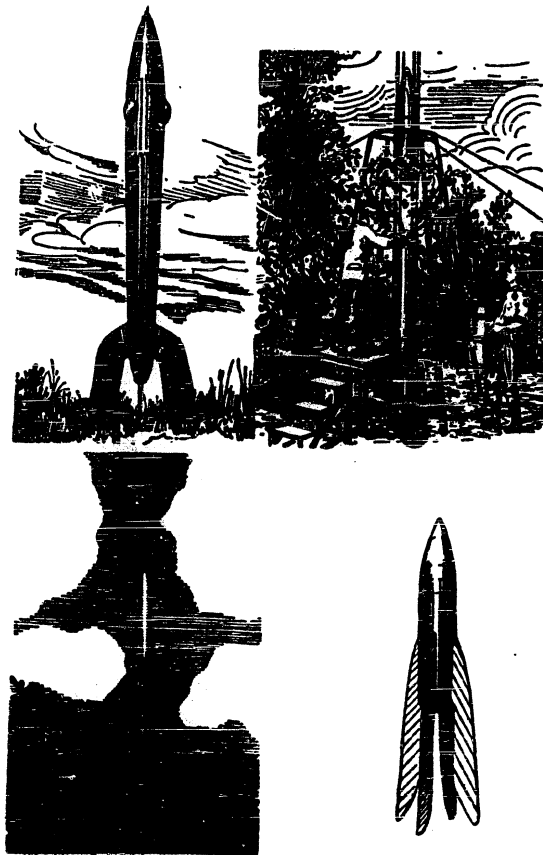
The enthusiasts of the Soviet science of rocket propulsion diligently worked in the direction of practical realization of Tsiolkovskiy's and Tsender's ideas.

With a special interest we recall the moment when the first rocket was released - it was a significant event in the history of rocket propulsion (Fig.21).

Here is the description of this event recorded by an eye witness:

...Twilight is ending. The installation of the rocket is progressing rapidly. When the refill with oxygen was accomplished, the container was taken away and every one went to the shelter. Two persons were left to attend the rocket. The oxygen pressure rises slowly... The one who attends the manometers signals, using his fingers, the number of atmospheres, 12 atmospheres... 13...

The heart is beating. Silence dominates and this minute appears frightfully long, almost limitless...



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STAT

Then comes a command: "contact". The fuel feed faucet is opened. (Contact accomplished). The mechanic turns the handle of a generator and... From the nozzle emerges a fire conus... Smoothly gliding along the guiding rails of the stand, the shimmering cigar dashes into the air. It moves faster and faster. There it is, high above in the blue sky. It turns then for a certain time it flies horizontally, later it begins to descend and finally it touches the tops of trees and slipping through the branches, buries its nose in the ground.

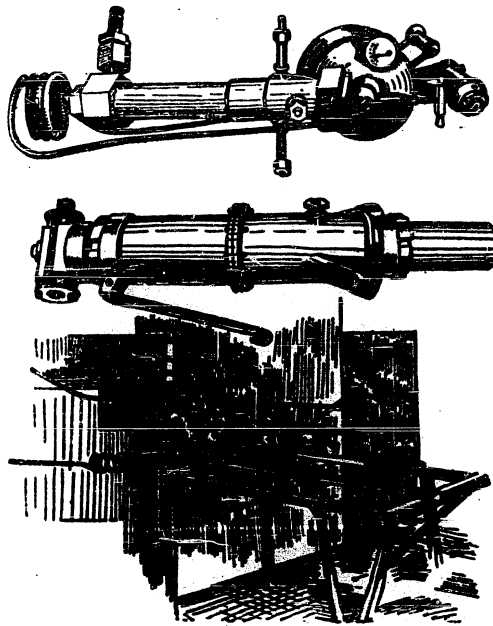


Fig.21. First Soviet Liquid-fuel Rockets and Motors.

A - First rocket launched in 1933; B - Refill of a rocket with oxygen - take-off;
C - Leningrad OSOaviakhim rocket; D - Tsander motor OR-1; E - Motor OR-2; sh - OR-2
motor on experimental stand.

All this does not continue long, but for the observers of this flight, the time ceased to advance. We all started toward the rocket. I placed myself behind the blindage - recalls one of the witnesses of this flight - and should have taken some pictures of the rocket in flight... The last warning "contact". A peculiar noise of a working motor begins to be heard. The rocket appears, becoming longer... smoothly it slips out of the stand and, with ever increased speed moves up. Accompanied by a roaring flame, the silver rocket cuts itself into the blue sky.

We all are full of joy. First, I made a shot of the wood instead of the rocket. A friend of mine, who was sitting in a tree while watching the rocket in flight, lost his shoe and failed to notice it.

The heart was full of pride, all difficulties forgotten. Everyone rushed to the fence behind which still could be heard the breathing of the rocket - the first Soviet rocket which was dreamed of by Tsiolkovskiy.

K.E.Tsiolkovskiy, who attentively followed the development of our rocketry, used to say, "My feeling became high when I saw how my successors quietly and without any noise are carrying out an important and complicated technical work".

In order to advance the ideas of Tsiolkovskiy, investigations concerning rocket motors and aircrafts were carried out. At the All Soviet conference concerning the study of stratosphere (1934) and at the All Union conference concerning the employment of rocket devices for studying the atmosphere (1935), reports were presented with data, containing the results of investigations in this direction. Particularly, there were given characteristics of winged rockets intended for a manned flight.

Still in the 30's, professor V.P.Vetchinkin, had accomplished a series of studies on the theory of aircraft and rocket propulsion. He mathematically investigated a flight of a rocket airplane with an operating motor and in gliding, vertical movement of the rocket and other problems. The study of the dynamic side of a flight of a rocket mechanism was undertaken by other Soviet scientists and



Isander, Fridrikh Arturovich (1887-1933). Born in Riga. He was graduated from Riga Politechnical Institute, Department of Mechanics in 1914. In 1906 he started to work on problems of Interplanetary travels.

In 1915-1919 worked at different factories in Moscow.

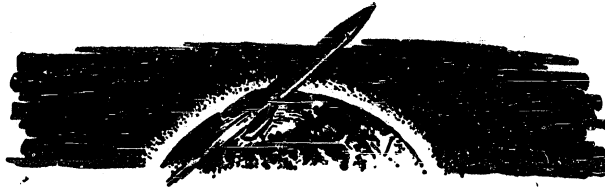
In 1920 proposed his first report on the interplanetary problem. Lectured in various cities on interplanetary flight theme. In 1924 organized in Moscow a Society of Space Travels.

From year 1930 worked on utilization of his own projects of rocket motors.

engineers also: a number of works were published still in the 30's in symposium "Reaction Motion" and "Rocket Propulsion". We shall name, for example, the works concerning stabilization of vertical motion in rockets, dynamics of winged rockets, rocket assisted take-off of airplanes and others.

In the 30's, there was organized a group which studied the reaction motion (GIRD). This group produced a number of engineers - active workers in the field of rocketry. The works accomplished at GIRD, contained many problems which later found an extensive application in modern rocket technology. The use of liquid oxygen, cooling by means of fuel, pump feeding, liquid fuel rockets, rocket aircrafts and other problems form the list of problems developed and studied by this group.

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FOURTH STORY

ROCKET PLACE IN NATIONAL ECONOMY

1. The Conquest of High Altitudes

In preceding stories we studied an extensive and multiform military employment of rockets.

But the rocket is not a weapon only. It becomes a truthful helper of men studying and conquering the nature.

High altitude research is the first important problem which would be solved with the help of a rocket in the future.

It is necessary to mention that here also the priority belongs to the Russian science. In 1903, at the dawn of aviation, Tsiolkovskiy wrote these remarkable words: "... I am offering a device to be employed for atmosphere research, i.e. a type of rocket, but a colossal and specifically built rocket".

With these words, the Russian science has opened a new chapter in investigating and conquering high altitudes.

High altitudes which envelop many interesting mysteries have been attracting attention of men from the ancient times. Daring explorers, armed with instruments have climbed the altitudes in airplanes and stratostates. Soviet heroes - astronauts Fedoseenko Uysykin and Vasenko, in 1934, lifted the "world's ceiling" up to 22 km. Underneath they left an impressive thickness of aerial ocean.

The siege of high altitudes has been carried since long ago, but many phenomena occurring in the atmosphere still remain unveiled.

Dependable and accurate instruments have penetrated the regions not entered by man. Miniature investigators of high altitudes - aerial balloons with instruments, ascended altitudes up to 40 km. This is the altitude close to that reached by super long range projectiles during the First World War. But no fragile instruments can be trusted to be carried in a projectile as well as no human being can travel inside devices described by Julius Verne. Yet we know that air balloons, similar to a child's toy balloon, are capable of lifting their passengers to the unaccessible heights. This, however, is also insufficient.

There are many different methods accepted for investigation of high altitudes. By observing the fall of meteors, silvery clouds, the radiation of light, sound and radiowaves, it becomes possible to establish many new data concerning aerial blanket of the earth.

It is proved that the highest layer of the atmosphere contains ozone. Intra-violet solar radiation decomposes oxygen on atoms which later are composed into three atomic molecules of ozone.

From the height of 100 km and up begins a new region of the atmosphere - the ionosphere. Ionosphere has remarkable characteristics.

Various studies show an interesting picture of temperature distribution at the high altitude zone.

It has been accepted that with the increase in altitude the temperature of the air gradually decreases coming close to the limit - absolute zero - 273°C .

It has been proved that it is completely different.

Starting from 11 km, the drop in temperature ceases and it remains constantly equal in average to 56.5°C below zero.

From altitude 25-30 km the temperature rise begins. At a 40-50 km height it is approximately $40-50^{\circ}\text{C}$. Later it declines to -80°C at altitude 80 km. In

region of ionosphere the temperature rises again and reaches 300°C at altitude of 200 km.

Later the temperature rise continues and remains almost constant. The future will show which one from these two assumptions, each bases of different methods of study, is truthful.

It is necessary, however, to mention that as a result of rarefaction of the atmosphere at high altitudes, the temperature of this region defines only the velocity of motion of gas particles, and not the thermal effects, as it is generally understood. Under the existing conditions, a body would not accept heat from the atmosphere because the amount of particles is small and heat condition is insignificant.

Rockets will lift instruments to altitudes which are inaccessible to any other flying devices.

These altitudes were reached previously only by rockets. Now rockets lift into the highest layers of atmosphere not a death cargo but automatic devices.

Various types of research rockets were built. Solid-fuel rockets were experimented with. Liquid-fuel engine with balloon and turbo-pump systems of feeding opened a possibility for climbing into stratosphere and ionosphere. For rocket launching, special launching stands and also tall metal towers attached with guiding rails can be used.

The head section is assigned for instruments, it is followed by sections for radioguidance equipment, fuel tanks, oxidizer tanks, motor (Fig.22).

Guidance is accomplished by means of graphite rudders mounted on the way of gaseous efflux, or by mounting the engine at the joint connected with gyroscope.

In both cases the direction of the flight can be changed by deflecting the gas jet. In the first case, the stream is directed by "gas" rudders, and in the second by rotating the motor. Rudders and gyroscope of the joint type are both guided by radio or automatically from the ground.

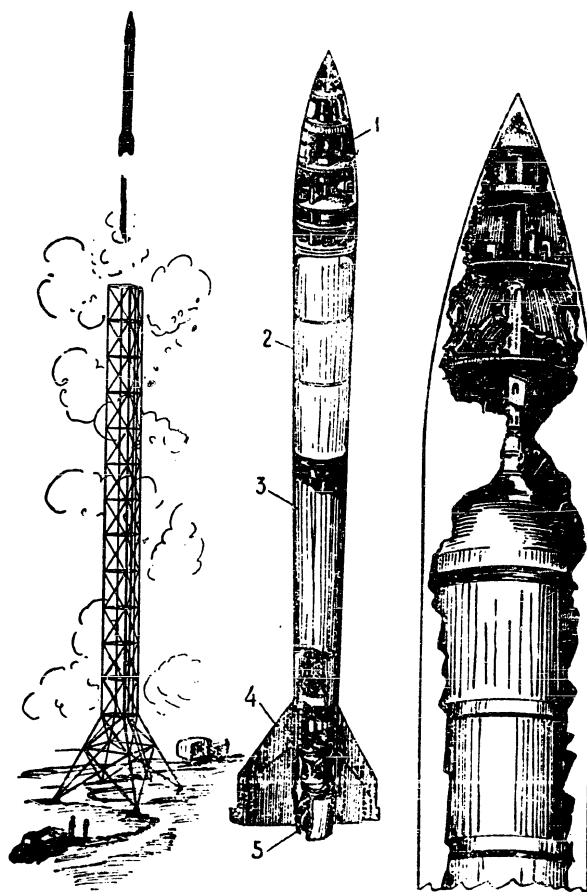


Fig.22. High Altitude Rockets.

A - Launching tower; B - The scheme of the rocket.

1 - Research instruments - gyroscopes and guiding instruments. 2 and 3 - Fuel tanks;
4 - Stabilizers; 5 - Rocket motor; V - Head part of a high altitude rocket of the
future with people intended for ascent to the upper layers of atmosphere.

Instrumental section accommodates a measuring device defining the grade of ionization of atmosphere, cosmic ray meter, air sample containers, spectrohelio-graph (an instrument for photographing solar spectrum). Thermometers and other devices. Instrumental section becomes separated by means of a mechanism, guided by radio and, later is lowered with a parachute. Sometimes the instruments and recorded data are contained in an armoured chamber which can withstand landing im-pact.

Telemetrical radiotransmitter (Telemetry is measurement) sends instrumental readings and data concerning motor operation simultaneously through several channels of communication, the number of which can be considerable.

Ascending gradually higher and higher, rockets will widen our knowledge of utmost layers of the aerial cover of the earth, and recheck the data received by other methods of study.

Up to date the modern high altitude rockets have reached high altitude range up to 400 km. Maximum height of the reach can be further increased.

With the help of these rockets many new interesting data concerning the con-struction of high altitude layers of atmosphere and phenomena occurring there have been received.

Temperature distribution in regions above 100 km was investigated and the results confirm the data received by other means of investigation. The air density at 200 km altitude was analyzed. The samples taken at high altitude layers show that the content of rare gases as helium, neon, argon, increases with the increase in altitude, i.e. the gas distribution evidently corresponds to their specific weight and no proper intermixing occurs. The heaviest accumulations of ozone have been discovered at altitude of 30-40 km.

Cosmic rays radiation was determined by means of meters installed in rockets. First experiments added some investments into the data describing the nature of radiation penetrating from the universal space. In spite of that the time of

observations is negligible and the velocity of motion is very high. Similar studies have been undertaken even before by means of radioballoons which reached altitude of approximately 30 km. Rockets furnished with meters climbed to 160 km height.

Photographs of the solar spectrum received at different altitudes, up to 90 km, show that the spectrum obtained in the layers above the ozone zone has an evidently extended ultraviolet region. It confirms that the intensity of ultraviolet rays increases with altitude and the ozone layer is actually the filter which protects the terrestrial surface from dangerous influence of this radiation. It became clear that the sun radiates also Roentgen rays, which are absorbed by atmosphere. Sky illumination was measured by means of photo-elements; the results confirm that the sky becomes darker rapidly and at altitude of 25 km the strength of light is 20 times weaker.

The atmosphere has some layers consisting of charged particles - electrons and ions. Instruments, lifted by the rocket, first accomplished measurements of concentration of particles at altitudes almost up to 400 km. Earth is a gigantic magnet, and its magnetic field was studied during these rocket flights.

By observing the smoke clouds, released from a flying rocket, it became possible to determine the direction and velocity of the wind circulating in the stratosphere.

Terrestrial surface was photographed from altitude approximately 200 km; pictures clearly show curved outlines of the earth, well indicate the details of its limits and clouds. From this altitude it becomes possible to photograph an enormous area of several thousand square kilometers.

Even the first data published in press, data on the results of flights of high altitude rockets, indicate high valuability of the new method of research of high layers of atmosphere, and in the future of the universal space. Only with its help, it is possible to check data, received by other methods, and to study the phenomena which are inaccessible for observation neither from the ground nor with

the help of sounding balloons, for example, in cases of ultraviolet, roentgen or cosmic radiations at high altitudes. That is why, during recent years, geophysics started to pay more and more attention to the rocket - the new weapon of the science, investigating aerial ocean.

2. Problems of the Present and the Future Time

The new method of air research is, in fact, in the first phase of its development.

Sometimes, in the process of experimenting with stratospheric rockets it becomes necessary to confront the difficulties which could not even have been foreseen.

Here, we shall mention several cases which occurred during the flight of high altitude rockets.

...The take-off was accomplished successfully, but after several seconds, the rocket began to spin about its axis too rapidly, one of the stabilizers became loose and fell off. The stabilizer was attached on antenna of radiotransmitter. When all these parts landed to the ground, the signals from the rocket should have been stopped, but they continued. It was found that a piece of the antenna cord had touched the body and it itself became an antenna. Thus, the rocket was continuing to signal during the entire time of the flight.

The other case occurred when the rocket took off straight up, as it appeared from the ground. The take-off occurred at night. First, during the operation of the rocket booster, a thick stream of fire ejected from the motor, could be seen; later, a narrow stream coming from the engine of the rocket itself could be detected at a considerable height. The operation of the motor ceased, but the stream of fire continued to rise up.

It was discovered that one of the graphite rudders, mounted on the way of gaseous stream, became incandescent and continued to produce in the air a jet of fire even when the motor operation ceased....

The landing of rockets was strictly vertical too... but it landed about ten km from the place of take-off. While it was flying, the earth position changed and the rocket landed somewhere west from the rocketodrom.

During one of the launchings, the rocket instead of taking-off straight up, started unexpectedly to fly along an odd trajectory and flew 200 km from the place of launching. It was proved that it was caused by the condition of a graphite rudder which was damaged during the start by a piece of ignition device thrown out through the nozzle. A part of the rudder was broken off, and the rudder itself was continuing to turn until it was demolished. That is why the rocket failed to follow the right direction.

After this case, it became necessary to dry the graphite rudders in ovens, thoroughly check by means of roentgen rays and test for a heavy load. To protect the rudder from damage by parts of the ignition device, it became necessary to cover it with durable carton covers which later could be burned in the stream of incandescent gases.

During the flight, a rocket rotates about its longitudinal axis and that makes the photo recording of the earth surface and of the solar spectrum more complicated. It became necessary to construct a special observing device which was maintaining a constant orientation of the spectrograph relative to the sun. To eliminate the rotation, the vapor issued from the turbo-pumps was ejected through the side outlets in the body.

The operation of instruments was also handicapped. A rocket was "dangling" in flight, and the film was passing before the window of the spectrograph more rapidly than was necessary. The entire length of the film was sufficient only for half of the course. The adapter, which was thrown out of the rocket, was found several days later.

Various handicaps were disturbing the radio record transmitting to the ground. The cause of it could not be solved for a long time. Later, with the

help of photocameras installed in the rockets, the pictures show that the stream of gases issued from the motor passed close to the transmitting antennas and caused the handicap in communications.

Cosmic rays enter in reaction with the substance forming walls of the instrumental section. In cases when the walls were fabricated from steel, the result of measurements were greatly distorted. It became necessary to manufacture the instrumental section entirely from aluminum and take some precautions permitting observing the phenomena occurring with the cosmic particles in the rocket mass.

The descent from high altitudes is a considerably complicated problem also.

To obtain necessary instrumental readings, the instrumental section becomes separated from the rocket and is landed by parachutes which open one after another. Sometimes instruments were included in a steel chamber, or attached to the body by means of bolts which were exploded over the radio from the ground. The chamber first falling freely, later reduced its speed of landing while passing through the dense layers of air with parachute attached. By using this method, records, data, spectrum prints, and pictures of earth surface were received. The landing of the body itself is considerably complicated because of its weight. The pay load, especially at the ascent to very high altitudes, is still not very big: so, a rocket which climbs to 400 km height is only 12 km. But the body with tanks, motor and different equipment, weighs much more. Until now, only instruments were successfully landed, the bodies of mechanisms were demolished at landing. This, of course, is not practical, because one rocket can accomplish tens of climbings. It is necessary to work out a method of a safe landing not only for the instrumental section, but for the entire construction.

The development of a rocket method of study of the stratosphere poses new problems to the rocket technique.

The extension of climbing altitude - the ceiling - is the first problem to solve.

A liquid-fuel rocket motor is the only type of engine which is capable of creating a gas jet in rarefied air of high altitudes and in vacuum space.

If a piston airplane motor is furnished with oxidizer, it becomes capable of operating in a vacuum space also, but it will not create any thrust because it requires air. Thrust is created by the operation of propellers.

The rocket ceiling is practically limited only by fuel reserve.

Therefore, it is important to increase the reserve of fuel in the rocket and to employ new, more effective fuel mixtures. It is possible, for example, to expect more efficient flying characteristics by employing ozone as an oxidizer.

The use of new high durable but light weight alloys for manufacturing rockets will reduce the overall weight or will permit carrying greater reserve of fuel while the weight remains the same.

Flying ceiling at vertical climb depends upon the velocity reached at the moment when the rocket motor ceased to operate. The rest of the course the rocket flies powered by accumulated kinetic energy.

A compound rocket develops higher final speed, than the speed developed by a single-stage, non-compound rocket. Therefore, its ceiling can be higher than that of a single-stage rocket.

A record height of 400 km was reached by a two-stage rocket with research instruments, at maximum speed equal to 2250 m per second.

Of course, a multi-stage rocket is more complicated than the simple-stage type and that causes many additional technical complications.

The guidance and construction of these rockets are complicated. The flying altitude can be extended by the use of novel fuels and materials. We can assume that by means of such rockets a flight through the stratosphere into interplanetary space is possible.

Only fifteen years ago such a supposition would seem to be fantastic. Large modern rockets can carry up to a ton of pay load. It seems that it is also possible

to lift a man in an altitude rocket to the upper layers of the atmosphere. Such a flight, without any doubt, will be the greatest achievement in the history of rocket flying at high altitudes. The rocket technology possesses all medium for building a passenger rocket for stratospheric climbing up to 200 km.

The load section must be furnished with an equipped hermetic cabin. It will carry a pilot, and perhaps, a second member of the crew, who will guide the flight, control the automatic operation, and carry the observations (Fig.22). Heating, oxygen supply and air refinery, protection from dangerous action of radiation, convenient observation, a possibility of immediate bailing out in case of an accident - all this must be taken into account by the constructor. The cabin must be furnished with a parachute and a stopping device for reducing landing speed. When the ceiling is reached, the cabin becomes automatically separated from the body and it begins landing, accompanied by automatic operation of braking the motor. While passing through the dense layers, the speed decreases to limits safe for parachuting, parachutes open and landing accomplished.

To prevent the instruments and the crew from landing impact, the gondole is furnished with an amortizator, which springs and eases the landing impact.

Acceleration created at take-off can be considerable - several times greater than the normal acceleration due to gravity. The duration of descent with operating motor is one minute long. A man can endure high acceleration only during a short time. Therefore, in the case of a passenger rocket, acceleration at landing and descent must be limited to the borders safe for living substances by means of automatic mechanisms, which regulate fuel feed, thrust and speed acceleration. Besides that, it is possible to construct a seat with an adjustable back. Acceleration can be easier withstood in a declining position. Autopilot and radiolocator, by the beam of which the flight will be guided, will help the pilot to guide the rocket.

3. Investigation of the Aerial Ocean

The developing of special instruments is an important problem upon which depends the progress of stratospheric research rockets. Instruments must be light, durable, simple, and at the same time capable of bearing a considerable overload created in the process of flying. If the instruments are mounted close to the rocket motor, then they must be well protected from thermal effects.

Rocket instruments must possess one more property - they must immediately react on all processes occurring in surrounded medium.

A regular thermometer, for example, is not efficient for measuring the temperature of a fast flying rocket because the rarefied air of high altitudes does not affect it.

To measure the temperature of rockets in motion, there were offered thermistors - substances whose electro-resistance changes with the temperature. Thermistors very quickly react on change in temperature.

The guidance was accomplished by radio mechanisms. The operation of the motor was controlled by radio; in case of deviation from the requested course, by acting upon the mechanisms of the rudders by means of radio, the rocket can be directed onto the correct course. Instrumental readings are recorded or transmitted to the ground. At the present time, there is a selfrecording radio equipment for receiving signals from flying radioballoons and rockets.

Soviet constructors have developed a light portable radio-transmitter and radio-sounding apparatus.

Method of radio signal transmitting from rockets is in close connection with such branch of radiotechnology as television.

In the future, a continuous conveyance of instrumental readings by means of special television transmitter will be possible.

The problem of photographing the earth and sky from high altitudes is also closely connected with this progress.

First employment of rocket for photographing terrestrial surface occurred first during the First World War. Then, there were accomplished some experiments with photo cameras lifted by rocket to low altitudes. However, the progress in aerophotographing from aeroplanes made the employment of rockets in this field unnecessary. But the limited climbing height of an airplane or a stratostate is limited by 2-3 tens of km. Altitudes, higher than this, can be reached only by means of a rocket. And now again, the idea of lifting photo and movie cameras to the high altitudes by means of rockets has been revived.

In the future, the process in radar technique and television will, perhaps, allow a transmission of images from a flying rocket to the earth.

High altitude photography can be beneficial for astronomy. Leaving behind almost entire layer of terrestrial atmosphere, the rocket acquires a position exceptionally favorable for observing heavenly bodies.

Air presence handicaps astronomical observations, distorting images. Therefore, very often the observatories are situated in mountains. A rocket can lift an instrument to an altitude where observations cannot be affected by air.

It is difficult to foresee all the benefits which will be exercised by using a rocket - the investigator of high altitudes, for science and national economy.

The progress in high altitude aviation, high speed flying, weather stations, long distance communication - all this depends upon the knowledge of high layers of atmosphere.

Air resistance existing at low altitudes limits the speed. To overcome it, a tremendous force is required. In rarefied high layers of atmosphere, the resistance diminishes and the rocket motor develops high flying speed of 2000-3000 order per hour and greater. High altitude operation depends upon the existing conditions: air composition, density, thermal effects, air currents.

Bodies flying at high altitudes become heated. A long-range rocket, the maximum speed of which is almost 5 times higher than the velocity of sound, becomes

highly heated to the end of its five minute flight.

Meteors, which penetrate the terrestrial atmosphere at even higher speeds, burn up, not reaching the surface of the earth. Only very large ones reach the earth surface.

The knowledge of conditions existing in the upper layers of the atmosphere is also necessary when it is required to choose flying altitude efficient from the point of view of resistance and heating.

As an agent, establishing these conditions, the high altitude research rocket is irreplaceable. A constant observation of atmospheric conditions has an important meaning for weather forecast. In the future, observations by means of sounding balloons, aircrafts and aerial balloons will be completed by data received by rocket balloons.

By lifting instruments to high altitudes, rockets will accomplish observations of the change in solar radiation and also electric and magnetic phenomena in the upper layers of the atmosphere due to the sun's action. Science is now facing a great problem - "Sun" - "Earth", i.e. analysis of Sun's influence upon the life on the Earth. These observations, without any doubt, will be helpful for the solution of this problem.

Rockets, by lifting radioinstruments to high altitudes, accumulate many valuable data about radiation of radio waves and on the possibility of radio communications during the high altitude flight.

The components of the upper layers of atmosphere as pressure, air composition, wind, intensity of cosmic rays, magnetic fields of the Earth, all this demands further systematic observations, and rocket method of investigation will play here an important role.

Flights of high altitude rockets will be a period preceding the mastering of inaccessible, at the time, regions of aerial ocean, and later the creation of an artificial Earth's satellite, a laboratory for investigation of universal space.

4. Rocket Stratospheric Flight

Investigations of high altitudes will be followed by flying at high altitudes.

A manned flight in a rocket at high altitudes is coming close to realization.

This problem is very virtual for the progress of national economy. Endless regions of our Fatherland demand a quick and convenient method of communication. The rocket will serve as an agent of such communication.

If in a long-range rocket, the explosive substance could be substituted by any pay load, for example, mail, we could accomplish transportation of urgent cargoes on long distance in short time.

Experiments with solid-fuel mail rockets had been accomplished long ago. Rockets had transported mail for a short distance in mountain regions, where the communication by other means is handicapped. The progress of rocket technique during recent years created a liquid-fuel rocket, the motor of which imparts it at maximum speed during 60-70 seconds of operation, and that several times exceeds the velocity of sound. The climbing altitude of such rocket is 100-200 km, and in the case of a complex rocket, even considerably higher magnitude.

Creation of new, more efficient rocket motors, employing more effective rocket fuels, development of new designs for rockets of multi-stage and winged type permits the increase in altitude and flying range in the future. Range increase in its turn, creates many complicated technical problems.

F.A.Tsander, who mathematically analyzed a flight and designed long-range rockets wrote: "...The flight of long-range rockets...in the close future will play an important role for transporting loads and men from one point of the Earth to the other".

The guidance of a rocket is considerably complicated. The rocket should be guided not only through the limited region of its trajectory to the moment when the motor operation ceases, but along the entire course, from the start to the place of destination. While traveling through dense layers of the atmosphere, the rocket

can deviate from the prescribed course. All unexpected deviations summarize at the end of the trajectory resulting in the fact that the rocket won't reach the destination. In case of long distances, even small deviations can compile eventually such "errors" which will make the landing of the rocket in prescribed point impossible.

Automatic pilots and radio control must secure the accuracy of the course.

Safe landing presents also a complicated problem.

The weight of a modern rocket exceeds 10 tons, and in the future it might be still increasing. The speed of rocket at the moment of entering the atmosphere exceeds the speed of the sound several times.

Air density at high altitude is very low. Therefore, the employment of, say, cargo-parachute is not a simple problem. A parachute cannot operate at high altitudes. However, the speed of the rocket while passing through the dense layers of the air is considerably high; a parachute cannot withstand such a powerful and immediately acting impact, created at the moment of its opening. Methods of parachute employment which would secure a safe landing of the rocket, without being detached, must be found. Perhaps, the final velocity of the rocket must be reduced. It can be accomplished by using a rocket motor for braking, by directing its thrust toward the side opposite to the motion. Such method requires an additional amount of fuel, and consequently results along the range reduction.

The flying speed in the process of motion rapidly grows. It leads to a heavy overload. The endurance of a human being with respect to overload is limited.

The body of a long-range rocket itself cannot oppose exceedingly high overload which, however, at the moment of its entering into the dense layers of atmosphere must become considerable at a degree that the rocket will simply disintegrate in the air.

Air brakes employed in high speed rockets must be automatic and must not disorganize the rocket stability.

A complex employment of a parachute and air brakes is possible; braking

reduces the speed of the rocket to the degree when the employment of a parachute becomes practical.

Load and mail rockets are not rockets of single action as combat long-range rockets. It can be efficient only when it is capable to operate regularly, transporting mail and cargoes to remote regions of our country. Therefore, the problem of landing acquired virtual importance.

The employment of rocket for mail delivery can be very efficient from the point of view of economy and advantage in time of post communications. Air-mail is the quickest type of post communications but would not stand the competition with rocket post transport.

So, for example, from Moscow to the Far East, a letter can be delivered by train in three weeks, by airplane - in several days. A high speed rocket transport will, of course, sharply diminish this term.

Very high supersonic speeds can be developed by an aircraft with a uniflow, jet-reaction motor. But the ceiling of such an aircraft is limited, because a uniflow motor is inefficient at high altitudes.

A rocket can climb to heights, where the air resistance of rarefied air is low and therefore, the velocity of the flight can be very high. There is a project of a passenger rocket, which can reach a speed of 4000 m per second and a maximum altitude of 300 km by its range equal to 3000-4000 km (Fig.23).

Rockets will permit the realization of the transportation of mail and loads from one end of the country to the other in record short time. Provided that the lifting capacity of a large modern rocket is approximately one ton, and in the future it will be, perhaps, even greater, it will transport a large amount of mail at a time. The transportation cost of delivery must be low.

Rocket mail transportation will play an important role in national economics.

Postal rockets, as well as high altitude research rockets, can be of multi-stage type.

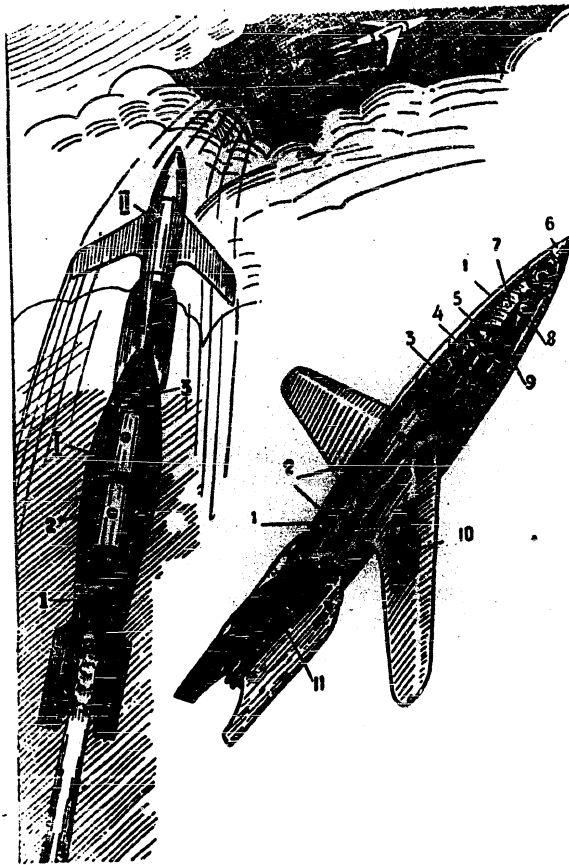


Fig.23. A Multi-stage Passenger Rocket.

- A - A take-off with a booster. I - Booster; 1 - Rocket motor; 2 - Fuel tanks; 3 - Parachute; II - Rocket;
- B - The rocket; 1 - Double covering with heat insulation; 2 - Fuel tanks; 3 - Payload; 4 - Oxygen and coolant balloons; 5 - Radioequipment; 6 - Nasal deflector; 7 - Cabin; 8 - Pilot; 9 - Retracted nasal wheel; 10 - Retracted wheel of main fuselage; 11 - Rocket motor.

Rockets intended for long-range flight can be furnished with wings.

A winged rocket virtually is an airplane. But unlike the airplane, the thrust of the rocket is greater than the weight and it requires wings not during the entire flight but mainly during its finishing stage. When a rocket enters the terrestrial atmosphere, it, having a high velocity, possesses high kinetic energy. Adding of wings permits the utilization of this energy for the purpose of extending the range of the flight by means of gliding. The lifting force of wings converts sharp diving of a wingless rocket into a smooth gliding landing.

Employment of winged rockets, however, introduces new technical difficulties. Wings possess not only lifting force, but simultaneously increase the weight of the mechanism and its resistance. Therefore, it is necessary to secure the required durability of wings and dependable aerodynamic properties.

How will a supersonic rocket-airplane look? Characteristics of such aircrafts of the future are the objectives of many speculations in avio-technical literature. One design represents an aircraft in form shown in Fig. 24. In the front part of the body is situated a hermetic cabin for the pilot with adjustable seat which eases the overload sensation at acceleration and maneuvering. The form of fuselage is similar to an artillery projectile with pointed front part. The lower surface is flat. Fuselage and wings while moving at high speeds produce a lifting force. A considerable space in the fuselage is occupied by fuel tanks. A retractable three-wheel fuselage, guiding-navigational and other equipment all this is principally familiar to the technique of today. The wings are comparatively small, of three-angle wedge form which is the most economical under the conditions of supersonic speeds. The tail feathering is situated in the position where it is not affected by air disturbances produced by the gas-jet of the motor (Fig.24).

The take-off is accomplished from a starting sled furnished with special rocket motor. The sled with the aircraft is accelerated along a special path, and after that begins the independent flight powered by energy accumulated during accelerating

and later by the motor. The aircraft glides a considerable part of the course, after the maximum speed was gained, and is capable, in such way, to move for a great distance without landing.

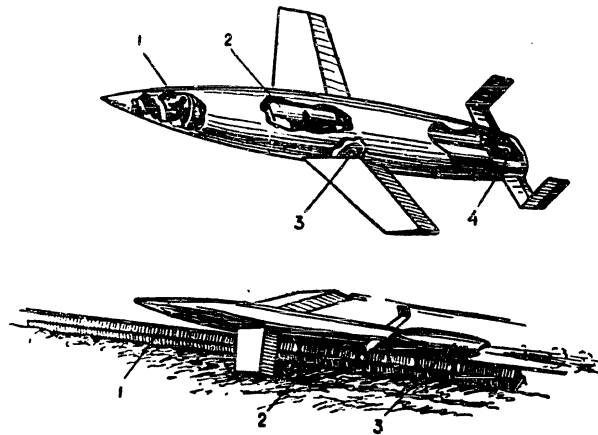


Fig. 24. A Supersonic Rocket Aircraft as Presented in One of Designs.

I - A scheme of the aircraft. 1 - A hermetic cabin; 2 - Fuel tanks; 3 - A retracted fuselage (nasal wheel is not shown); 4 - Rocket motor.
B - Starting device; 1 - Starting path; 2 - Sled; 3 - Rocket motor in sled.

Wing load or weight corresponding to unity of a wing area is an important indicator for aircrafts of modern type.

The more the wing load, the higher the landing speed, and it cannot be exceptionally high. Liquid-fuel rocket aircrafts have wing load greater than aircrafts of piston type and jet-reaction motors.

The wing load of winged rockets will be even higher due to resistance, the span of the wings must be small, and overload experienced by a rocket during the flight is higher than this created in airplanes. The wing area, consequently, must

be relatively small, and as a result, for every square meter of the area will fall a bigger construction weight. According to it, the landing speed of a winged rocket is higher.

A winged rocket, if compared with a conventional airplane, and even with a reaction plane (with a jet-reaction motor) as well as an airplane with a reaction motor has another peculiarity. It consists in the fact, that reaction motor of an airplane, as well as of a rocket, consumes, as we have seen before, very large quantities of fuel. Because of this feature, the weight of the reaction flying mechanism changes during the flight, and consequently, the load on wings changes also - to the end of the flight it diminishes.

This circumstance permits a supposition that the landing speed of a winged rocket would be not too high, in spite of tremendous supersonic flying speed.

Mechanization of wings and employment of skis will secure a safe landing. To reduce the landing speed, braking can be used, as it was indicated above.

It is possible that wings of retractable type will be designed. Wings are required for gliding and landing. A mechanism, operated by the pilot or by radio from the ground, extends wings from the body of the rocket, before it enters the dense layers of atmosphere, to avoid sharp braking and dangerous overload.

The peculiarities of a supersonic flight demand thin wings with a sharp front rim. A wing of this kind must be custom made. Accommodation in wings of ribs, longerons, and stringers, becomes complicated and even more complicated is accommodation of fuel tanks.

It is supposed that "supersonic wings" will be fabricated by forging and later processed on metal cutting benches.

Plastic chemistry greatly progresses during recent years. There were created plastic masses as durable as metal, capable of withstanding thermal and chemical effects. There is a possibility that in the future, plastic compounds of a special formula intended for manufacturing wings for rockets and rocket aircrafts will be

used.

Previously we have mentioned the advantages of high altitude flying.

Let us now analyze the problem of a passenger rocket flight in stratosphere.

Unusual conditions, specific to high altitude regions, produce numerous handicaps on the way of realization of a rocket-manned flight into the stratosphere.

A human being placed under conditions of high altitudes must be protected from "high altitude sickness" - sensation of small air pressure; must be supplied with air of consistency suitable for breathing, and liberated from damaging body secretions. The pilot must be accommodated in a hermetic cabin or dressed in a protective suit. Aviation and air navigation possess a great experience in field of high altitude flying. But rockets will reach altitudes where a human organism is exposed to even greater unexpected dangers.

By reaching high altitudes, the rocket will leave behind it almost the entire earth atmosphere. Dangerous influence of solar ultraviolet radiation must also be considered. It complicates the development of protective suits or of a cabin for a high altitude rocket which must be protected against dangerous influence of radiation.

Passengers must be protected by a protective layer placed in covering of the suit or in walls of the cabin. It is possible that protection of armoured type from meteor danger will be required because the flight will proceed at altitudes where air is completely absent and cannot serve as a protector against meteoros. It is true that the possibility of this encounter is very doubtful.

Separation from the Earth, take-off, climbing, the change in direction of flight, will be accompanied by the change in speed. Therefore, during a certain period of time, man will experience the action of acceleration. The importance of it had been proved by the experience acquired by high speed aviation.

Conditions for pilot operation becomes more complicated with the increase in speed. While accomplishing figure flying, a sensation of overload is accompanied

by upset of blood pressure, vision, heart operation, and brain activity due to acceleration. To ease the dangerous influence of overload, the chair of the pilot is designed of an adjustable type, because it has been proved that the harmful action of the overload on the body depends upon the position of the body and can be reduced by accepting certain position. There are projects of cabins accommodating pilot in prone position, which is beneficial for the body. There were attempts to design a special pilot anti-overload suit. In case of rockets, overload is even higher than that experienced in aviation. Therefore, the protection from overload will be very important in manned rocket flight.

On the other hand, in the case of a free flight in vacuum space, with motor in shut-off position, overload will be completely absent. This condition of "absence of weight" - imponderability, has been described by the authors of many space stories. However, to foretell now the real influence of the partial weightless condition on human organism is impossible.

To protect the safety in flight, physiological conditions of supersonic flight must be carefully studied.

A man cannot be replaced by instrument and vice versa. They supplement each other. Complicated conditions existing at high altitude regions demand complicated and accurate instruments for carrying out observations. Such instruments exist, but need improvement and adaption to conditions of high altitude flights. Instruments are subjected to the same overload which influences the human body. All accomplishments of the modern precise instrument manufacturing must be utilized in rockets. It is necessary that all equipment is as light as possible.

Taking into account difficult conditions of the work for the pilot of a rocket, it is important to strive for a complete automatization of motor operation, guidance and instruments.

The progress in radar technique will find proper application in the future supersonic rocket flights.

Ground radar stations will be continuously determining the position of the rocket and producing a clear picture of rocket flight. Radar altimeters will indicate the height, for at high altitude, the conventional aviation altimeters - aneroids are useless. Landing can be accomplished with the help of radar also.

Progress in radar operation introduces a communication by means of short waves which penetrates through the ionized layers of air, handicapping the use of long waves. The possibility of travel to the Moon was theoretically proved by Soviet scientists - academists L.E. Manelstan and N.D. Papaleksi. This experiment was realized during the post-war years. It has been confirmed that very short waves can penetrate through the atmosphere and travel in interplanetary space. A distance to the Moon measured by means of reflected signals coincides with the data received by using astronomical methods.

Shortwave communication, employed by radar, is the problem of the future technology. The solution of it is important for high altitude research.

To extend the height of rocket flight, rocket constructions must be developed.

One of the problems is the development of a rocket motor, increase in thrust, duration and dependability of rocket mechanism operation.

High speed rocket flight introduces many new problems as rocket design, better corresponding to high speed flying and other questions connected with aerodynamics of a flying rocket mechanism.

Rockets intended as a specific flying laboratory, equipped with measuring apparatus and telemetrical transmitters are used for aerodynamical investigations. By means of these rockets, flying tests, for example, wing profiles, rocket airplane models under conditions of supersonic speeds can be accomplished. Such experiments bring additional and more accurate data used for completion and detailing of data acquired by means of aerodynamical tunnels, and are very useful for establishing best constructions of high speed flying mechanisms.

Compound rockets can also be used for passenger rocket transportation.

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They have great possibilities. The range of flight in this case increases. So, for example, in the case of a winged rocket, with 500 km range, a rocket booster is added, it converts it into a stage rocket with range of 4800 km - 10 times increase.

During the war, the Germans have developed a design of a rocket intended for flying from Europe to America. The rocket was designed consisting of two-rockets: a booster and a winged manned rocket. The rocket motor of the booster should be developing a thrust equal to 150 tons and capable of imparting an initial speed of 2700 m in one second (10,000 km in one hour) to the passenger rocket. After a height of about 300 km was reached, and the amount of fuel was exhausted, the booster was automatically separated and the winged rocket could continue its course. The booster was landed by means of a parachute with 2-layer dome. Between the layer space contained compressed air securing smooth landing. Then, the motor of the rocket was switched on, and after that it began gliding.

In technical literature are offered many designs of rockets capable of reaching even higher speed ranges, for example, such as intended for a non-stop flight around the world. It is necessary to mention that the start weight of such rockets is very big and that diminishes the value of the pay load. This is another problem of the future.

Technical progress will find ways of creating passenger rockets with large lifting capacities, high ceiling, speed and long range. Thus, the rocket will solve the problem of passenger transport which is important for our fatherland, vast regions of which occupy one-sixth of the entire earth's surface.

The next problem is: how will rockets fly at high altitudes when the temperature there reaches several hundred degrees? This, at first glance, very serious handicap, is actually not essential.

The air at high altitudes is strongly rarefied. At the height of 50 km air density is 1000 times less than at sea level. Therefore, the heat transfer from

the air to the rocket is very slow. The temperature of the rocket depends on the number of molecules encountered by the surface of the rocket. And because the air is rarefied, the number of impacts will be insignificant.

The heating of the rocket as a result of air friction will be high, but considerably lower than at the flight through the lower layers of the stratosphere.

The influence of solar rays will be considerable only at relatively high altitudes.

Thus while flying at high altitudes, a rocket would not experience overheating and, perhaps, the problem will be not cooling, but heating. Only at the time of passing through the dense layers of air, the thermal effect due to friction can be high, and that must be considered while planning a rocket flight in stratosphere.

We have investigated the employment of the rocket in solving three principle scientific and national economic problems: high altitude research and other scientific problems, high speed freight and postal long-distance communications and high speed air transport.

The mastering of high altitudes and high speeds will be the principle practical employment of rockets. And the perspective of such employment gives us a right to say that a rocket will be one of the agents of scientific - technical progress, for establishing power of the country and progress of its welfare and culture.



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FIFTH STORY
FROM FICTION TO SCIENCE

1. Interplanetary travels

The idea of a flight into interplanetary space was born before rockets were introduced. About "rising to the sky", flying toward the sun and stars, many legends have been composed far before the science of world creation came into existence.

Projects on interplanetary ships appeared as the result of technological progress.

For traveling to other planets, terrestrial magnetism, the pressure of light, gun shells, centrifugal force and many other things were proposed.

They were all fictions.

Only from the moment when the rocket science was established, the problem of interplanetary flight became real.

Development of a certain speed for overcoming the force of gravity is required. Eight km in one second and a body becomes a satellite of the earth, the second Moon. It will circulate around our planet for always. At speed rate equal from 11 to 16 km per second a body moving in the direction of the earth's movement along the orbit can become a sun's satellite and travel along the closed path in the sun's system.

By choosing a special trajectory, it is possible to direct the body toward any desired planet and to accomplish the way back. 17 km per second is required for a body for leaving the sun's family forever and traveling toward another sun - a star, and for becoming an interplanetary traveler.

Several km in one second... How can it be accomplished? Can there be in existence such flying mechanism which would be capable of developing such gradual speed which would not destroy passengers? Naturally, the employment of the speed champion-gun shell has been thought of. But it was in vain. A discharge and firing are not applicable here, for even if it would be possible to fire a shell into interplanetary space, then there could not be even a thought of a manned flight with the return to the earth.

It became apparent that there is a real technical possibility of developing cosmic velocities. It is possible to build a space ship, which would gradually, without any danger due to acceleration, for a human body and instruments, develop a required speed and will depart for a cosmic travel. The ship will be guided in the space; the direction of the flight, velocity, acceleration can be changed by the pilot, relatively to the calculations of the navigator. Finally, the fuel reserves secure the return to the home planet.

This space ship is a rocket. When the laws of rocket motion were discovered, it became clear that the conquest of the space will be accomplished by the rocket.

It has been mathematically proved that a rocket can develop such velocities which would be sufficient for astronomical travels also. However, the fuel reserve must be exceedingly high, for example, according to calculations accomplished by Tsiolkovskiy, it is 200 times the weight of the rocket itself for a flight to the Moon (at jet velocity equal to 2000 m per second). Tsiolkovskiy has proposed a design of a multi-stage rocket consisting of several separate rockets, one of which carries the pay load and others serve as boosters carrying main fuel resources.

Now we can visualize the general outlines of the space ship of the future.

A passenger rocket contains a hermetic cabin furnished with all the necessary utensils for living and studying. It contains scientific instruments, guiding mechanisms, radio equipment, photo- and movie cameras, heating oxygen-supply system, regeneration and air conditioning. Fuel tanks are situated in the middle and rocket motor in the stern. In the freight section are collected protective suits intended for entering vacuum space, food and other cargoes. The cabin can be transformed into a landing glider after it becomes separated from the body of the ship. The covering consists of two layers, each booster has fuel tanks and a motor. They gradually accelerate the whole rocket and after the fuel has been exhausted, the booster is separated.

Exceptional heaviness is experienced while the speed is increasing. Its value can be limited to ranges suitable for a human organism. To overcome the acceleration easier, passengers are placed on chairs with adjustable backs. The rocket will be piloted automatically. Later it will enter a phase of a free flight due to attraction to heavenly bodies. The ship seems to be falling on the planet, and while falling in a vacuum space, a body loses its weight. Phenomena of imponderability appears. All objects situated inside the cabin are moving in the space with a speed experienced by the cabin itself; when acceleration is absent, is it impossible to overtake an object traveling at an equal speed? The wonders of the weightless condition are not wonders at all, and it has been proved by experiments in the field of physics that free falling bodies are imponderable. When coming closer to a planet, to accomplish a smooth landing on its surface, the speed of the rocket must be reduced. If the planet is atmosphereless, then the ship reduces the speed of movement by directing the stream of gases from the motor toward the opposite direction (toward the surface of the planet), later a tripod landing device is retracted from the body and serves as a landing place. Through the sluice with two trap doors, the travelers will leave the cabin. If the planet has an atmosphere, it can be used for slowing down during the landing due to air resistance.

And circling, the rocket enters the atmosphere, reducing the speed gradually until it comes to a smooth glide, accomplished by means of retractable wings. That is the way of landing on the earth's surface.

Rocket technique greatly progressed during the last several years.

A modern, large rocket develops a high velocity equal to two km per second, whereupon the weight of the fuel exceeds the weight of the empty rocket 3-4 times. It is very close to the first "circular" cosmic velocity. The calculations show that a multi-stage rocket could accomplish a space flight even now and become an earth's satellite.

Modern rocket aircrafts, winged rockets, fly at speeds higher than 1000 km per hour. The amount of fuel and also the flying range is considerably small. As we can see, an aircraft-rocket is still far behind the space ship. However, there are under construction supersonic mechanisms and a supersonic flight at speed of several thousand km per hour is a problem of the comparatively close future. Gradually the rockets will be climbing higher and higher, and flying faster and faster. Following the instruments, man will ascend now unaccessible altitudes. A high speed air transport will be an every day reality. A new, effective fuel, new durable materials, new more perfect instruments - all that is required for the creation of the first passenger cosmic rocket to be produced by science and technology.

2. Creators of Astronautics

The problem of interplanetary travels has been theoretically solved, and the honor of solution belongs to the Soviet science (Bibl.4).

K.E.Tsiolkovskiy is the creator of this new science. His followers have greatly contributed to the development of astronautics. We can be proud that our country became the Fatherland of theoretical and practical basis for interplanetary flying. Russian science has made the first steps on the road toward the stars by solving the difficult problem which has long been looked upon by all mankind.

The idea of interplanetary travel has been generated long ago as well as the idea of flying in the air. But only with the appearance of Tsiolkovskiy's works, in which the problem of interplanetary travel was thoroughly investigated, scientific and theoretical basis for cosmic travels, were established. In the end of the past century, he developed the theory for a rocket flight and proposed an idea for a rocket interplanetary flight.

In a manuscript, "Free Space" of 1883, which was found in Tsiolkovskiy's archives, is indicated that the possibility of employing rocket principles of propulsion in interplanetary space, is real. In 1896, Tsiolkovskiy started to write a scientific fiction, "Outside of the Earth". The contents of the book clearly prove how definitely he intended to use a rocket as a medium for interplanetary flight. The fiction, as Tsiolkovskiy related, was written "after numerous calculations had been accomplished".

Tsiolkovskiy specified principle constructions and working principles of the rocket, indicating the possibility of employing an automatic guidance mechanism regulating the speed and the direction of flying mechanism by prescribed law. He also offered some calculations for the flight, a table of speeds and covered distances, relative to the flying time.

Still in 1891, in an article "How to Prevent Delicate Objects from Percussion", Tsiolkovskiy expressed some ideas concerning the possibility of preventing objects from harmful actions of overload. These ideas have been developed by him later in a book, "Dreams About the Earth and Sky and Effects of Universal Gravity (1895). He had foreseen some methods of protecting human organisms from the damaging action of heavy overload by means of immersing it into a liquid, the density of which is equal to the density of the human body. In his latest works, he again and again mentioned this problem. In a work written in 1895, Tsiolkovskiy offered an idea about creating artificial conditions on the earth which would be equal to the ones experienced during the interplanetary flight. He described a rotating and falling

laboratory, in which creating artificial high overload is possible and imponderability for the purpose of preliminary training of the members of interplanetary flight can be experienced.

A rotating laboratory represents a large enclosed dish. If the rotation is even, without any impetus, then a man placed in it won't feel the rotating movement, as we do not feel the earth's rotation, but will only experience overload generated by action of centrifugal force.

Centrifugal force created at rotation generates feeling of overload, analogous to that which is experienced by a pilot of a cosmic rocket at moments of take-off, turns and landing. During falling, the feeling of imponderability is created, as in the case of a flight, in a cosmic rocket at a constant speed. Tsiolkovskiy has proposed to construct rails, shaped in the form of a horse shoe, vertically installed and to direct a carriage along them. During the fall (movement along the straight railing downwards), passengers will experience the sensation of imponderability - absence of weight.

In the same work Tsiolkovskiy described the living conditions during an interplanetary flight. He proposed to use the solar energy by means of plants for establishing living conditions similar to those existing on the earth. Plants which can live only with the help of the sun's light, absorb the carbon exhaled by man and produce oxygen necessary for respiration and supply fruits used for food. During the flight in interplanetary space, plants will purify the air and feed man.

Tsiolkovskiy indicated a possibility of artificially created overload in a living space by means of centrifugal force originated by rotation.

We understood a thorough study of the early works of the scientist to show that still in the end of the past century he produced many original ideas in the field of space travel.

In 1903, Tsiolkovskiy published his classic work, "Investigation of Universal Space by Means of Reaction Instruments". This work was much more progressive than

the conclusions of foreign investigators. Abroad, the works describing the theoretical problem of rocket propulsion and interplanetary travel had appeared considerably later. So, in France, studies that were repetitions of Tsiolkovskiy's work were published in 1913, in America only in 1919, in Germany in 1923.

Tsiolkovskiy substantiated the advantages of a rocket as a medium of interplanetary flight and indicated the principle scheme of such a rocket and the theory of its flight.

In the works describing the techniques of a space flight, which were thoroughly studied by him, many prospective ideas appeared.

He examined questions of the construction of the space rocket - its form, material, motor, guiding mechanisms, and described different types of such rockets (Fig.25).

Proving theoretically that the development of cosmic speed by a rocket is possible, if the relative amount of fuel is sufficient, Tsiolkovskiy practically studied the ways of developing this speed.

Still in his scientific fiction, "Outside of the Earth", he mentioned the idea of a multi-stage space rocket. "From a simple rocket", wrote he, "-we moved to a complex one, i.e. one compiled from many simple ones". - and further he described the working principles of such a rocket.

Tsiolkovskiy understood that the existing fuels are not sufficient for a rocket, for it requires a relatively large amount of fuel for developing cosmic speed and introduced methods for overcoming this difficulty.

Developing the idea of a multi-stage space rocket, he proposed another variation which is called a cosmic escadra. That was a combination of similar rockets with simultaneous motor operation, using one-half of the fuel. Then the remaining fuel was transferred and the motion was continued by the other half of the rockets carrying full tanks. The speed gradually increased. After several transfusions, only one rocket of freight or passenger type was continuing the flight at the re-

quired cosmic speed.

The importance of fuel in the process of speed development has been indicated by Tsiolkovskiy still in his first works on rocket propulsions. The greater the

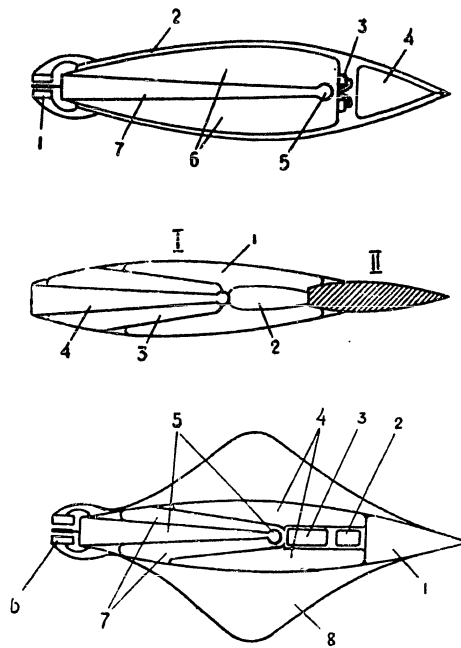


Fig.25. A Scheme of Tsiolkovskiy's Rocket.

- A - A space rocket; 1 - Gas rudders; 2 - Double covering; 3 - Fuel pumps; 4 - Cabin; 5 - Combustion chamber; 6 - Fuel tanks; 7 - Nozzle.
- B - A complex multi-stage space rocket; I - An auxiliary rocket; 1 - Oxidizer tanks; 2 - Fuel pumps; 3 - Fuel tanks; 4 - Nozzle; II - Principle rocket.
- C - Winged rocket; 1 - Cabin; 2 - Motor gear for pumps; 3 - Pumps; 4 - Oxidizer tanks; 5 - Combustion chamber and nozzle; 6 - Gas rudders; 7 - Fuel tanks; 8 - Flat wings.

speed of the gas jet, i.e. the more energy is created at combustion, the higher is the final speed of a rocket. The Tsiolkovski works indicated the ways of development for the chemistry of rocket fuels. Tsiolkovski also studied the hazards which can be encountered by space travelers, such as meteors, harmful action of cosmic and solar rays and others. He came to a conclusion that they can be eliminated and do not handicap interplanetary flying. These conclusions had been confirmed by modern conceptions.

Tsiolkovski's accomplishments have been acknowledged by the entire world. In 1954, the council of the Academy of Science of USSR established a gold medal in honor of Konstantin Eduardovich Tsiolkovski, awarded for the best works in the field of interplanetary communications.

The establishment of this medal indicates the importance of the cosmic problem.

Many other Soviet scientists, followers of Tsiolkovski, successfully continued the work in the field of the theory and technology of space travels. They developed many original and technical ideas, very virtual for astronautics.

One of the outstanding scientists, who greatly contributed to the field of astronautics, was the Soviet scientists Friedrik Arturovich Tsander.

In 1919, Tsander started to study an original idea - a winged space rocket - which uses the parts of its construction as fuel, after they become unnecessary.

By developing this idea, Tsander tried to create cosmic speeds with a considerably lower technically possible weight of the rocket and by relatively acceptable amount of fuel.

In 1924, an article written by Tsander "Interplanetary Travels" was published.

There Tsander described his idea of a winged rocket which was a combination of an airplane and a rocket. A space rocket, of Tsander's idea was connected with the airplane by means of a special construction. The airplane has wings reminding those of aircrafts of conventional type, tail feathering, fuselages and aviation motor with a propeller. The rocket itself forms the fuselage of this aircraft and has

small additional wings.

This complex rocket first climbs in low, dense layers of atmosphere, as a regular airplane, using lifting force of its wings and thrust of the propeller. In higher, rarefied layers of atmosphere, where a regular aviation motor with a propeller is unsuitable, the flight continues by means of rocket motor.

Such winged rocket is capable of undertaking a safe landing on planets possessing atmosphere by using its additional wings; the passage through the layers of earth atmosphere are also simplified.

Tsander offered to retract the carrying surfaces, aerial propellers, airplane motor and other parts which become unnecessary, melt them and eject the melted metal increasing by this, the thrust of the rocket.

This method reduces the amount of fuel carried by the rocket necessary for producing cosmic velocities. Tsander underlined that "this represents a safe guarantee in respect to developing a tremendous speed, necessary to overcome the earth gravitation".

Tsander thoroughly examined ideas offered him of utilizing metal parts of the construction of space rockets - airplane. These parts, after they become unnecessary, can be used as fuel.

"The Conquest of the Space" - was the name of the book written by Yuri Vasilisvich Kondratyuk. The book described space traveling and its history is very interesting.

Yu.V.Kondratyuk personally accomplished an original study on the theory and technique of rocket propulsion. "By accepting the theme concerning interplanetary flight, - wrote Kondratyuk, - I at once accepted the rocket method of motion".

After the principle formula of theory of reaction propulsion was established by defining the rocket speed in relation to amount of fuel. Kondratyuk, as a result of calculations received, data indicating that to undertake a space flight, a rocket requires an amount of fuel which is not possible to be carried. To overcome



Kondratyuk Yuri Vasilievich (died in 1942), Russian mechanic and inventor, the author of an essay "The Conquest of the Space", in which he studied problems connected with rocket space travels and proposed a series of original ideas, highly important for Rocketry and for the progress of space travels.

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this handicap, he developed, as he calls it, "antitoxin", which consisted of using air resistance for slowing down while landing on the earth surface (fuel can also be economized) and the establishment of an interplanetary base-station for space ships.

To realize the flight to other planets, a velocity equal to approximately 10 km per second is required. If a rocket starts a flight not from the earth, but from an outside of the earth station, the necessary initial velocity can be smaller. From the other side, to reach an outside of the earth station, a rocket requires a smaller amount of fuel than for a non-stop flight. After the fuel reserve was established, the rocket can continue a long-range space passage, and accomplish the flight with landing on other planets.

Kondratyuk, like Tsander, proposed to use wings at the moment of take-off.

He carefully studied the theoretical side of the flight, the efficiency of wing operation at take-off, and also questions connected with the overheating of the rocket while passing through the atmosphere.

His idea of "a landing glider" is original. He proposed to convert a rocket into a glider with the intention of creating a braking effect at landing on the earth. The rocket disposed of all unnecessary parts of its construction when entering the dense layers of atmosphere. Remaining were only the pilot's cabin, connected to a carrying surface - a wing, and also a long tail and tail feathering. These parts of the glider must be manufactured of heat resistant material because they are subjected to a high temperature when moving at high speed. The glider was carried along disassembled.

The construction of the combustion chamber and the nozzle of the rocket motor, the equipment of the space ship and guidance, the course of travels, landing to the earth, the program of works required for preparation - this is only a short list of the problems investigated by Kondratyuk in his work.

The works of the famous worker of science, Konstantin Eduarovich Tsiolkovskiy,

are successfully continued in our country, the fatherland of aviation, rocket propulsion and theory of space communications.

In the field of theory and technology of space flights many other scientists and technicians have worked and worked. Their contributions move the new science - astronautics, originated in our country - forward.

3. An artificial Earth's Satellite

"First important step of mankind consists in traveling beyond the limits of atmosphere and in becoming an earth's satellite", - wrote Tsiolkovskiy. The establishment of an artificial satellite will be the most important phase along the road to universal space.

Development of initial cosmic speed is connected with serious technical difficulties. Only a stage rocket can reach it, but the initial weight of such a train, as it was shown in rough calculations, is tremendous, and the pay load, on the contrary, is negligible. So, for example, a three stage rocket, offered in one project, consisting of now existing large stratospheric rockets, weight approximately 160 tons, with 50 km pay load. To promote the start, a series of turbo-reaction motors are provided, and besides that, a take-off is accomplished from a start platform, situated several kilometers above the sea level (Fig.26).

Thus, although the initial cosmic speed is in the possible limits of modern technical conditions, a considerable increase in the pay load presents certain difficulties. The initial weight, particularly, greatly increases. According to the other project, a four stage rocket has an initial weight equal to 900 tons and is capable of lifting 700 kg of the pay load. The project also specifies a motor, operating under a greatly increased pressure in the combustion chamber.

However, in a rocket satellite with a small load, it appears possible to install an automatic beyond-the-atmosphere laboratory, transmitting instrumental readings to the earth. Instruments for study of solar and cosmic rays, short-wave transmitter - such is possible equipment of this laboratory.

The establishment of an artificial satellite of the earth, has a great importance. The possibility of conducting observations of atmosphere during a long period of time, without any doubt, will produce new data on the activity of the sun, cosmic

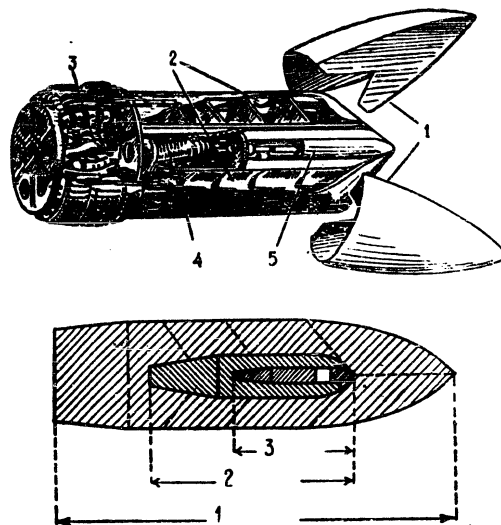


Fig.26. Layout for an Artificial Earth's Satellite.

1 - Disposed tanks of the first stage. 1 - Disposed tanks of the second stage;
3 - Motors of the first stage; 4 - Motors of the second stage; 5 - Rocket-satellite with instruments.

radiation, high altitude phenomena occurring in the aerial cover of our planet, accomplishment of regular observations of cloud formations, etc. All of this is in close connection with the life on the earth. Meteorologists justly acknowledge that atmospheric phenomena, occurring at high altitudes have influence on weather. The conditions of Ionosphere which immediately depends upon the processes occurring in the sun is very important for communications. Thus, the laboratory established

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on the satellite will help to solve these problems which are virtually important for national economics.

The operation of research rockets is very important too. On establishing the satellite, geophysics, solar service, physics of cosmic rays will use such medium for investigation, which opens a possibility of studying processes occurring beyond the earth, under conditions very specific for observation.

Successfully accomplished experiments on locating the moon, present a base for the development of projects related to super range radio communication by means of short waves.

As it is known, ultra short wave communication is possible only inside the limits of direct visibility due to the peculiarity of their expansion ability, and that limits the distance of transmission of images and sounds. By means of intermediate stations (retranslation), and particularly ones situated above the earth, for example, mounted in airplanes and helicopters, the transmitting range can be increased. In the case when radio-waves are directed toward any reflecting surface in the space, the reflected signals would be accepted at a considerable area enveloping almost half of the earth ball.

It has been proposed to use the moon as a screen for reflecting these waves and respective experiments had been concluded.

It has been proposed to use an artificial satellite in the form of a ball, as a radio-wave reflector, which possesses a good reflectability (Bibl.5). At the distance of approximately 6 times the radius of the earth (about 35,000 km) it would complete a round trip in approximately 24 hours. For a transmitting station situated on the equator, it would be located always in the zenith, and then it would be very convenient to, for example, televise a picture which could be received by the entire hemisphere.

A rocket would transport a satellite to the required altitude, imparting its required velocity and direction of movement along its orbit, which would be continued

without any expenditure of energy.

It is necessary to mention that the problem of creating an artificial satellite has attracted serious attention of foreign technical science. In countries of imperialism this problem is being discussed from the point of view of a possibility of using the satellite for aggressive purposes. A retranslation station is necessary for guiding rocket projectiles of long-distance action. Only in countries of democratic camp, the rocket technique serves the interest of peace, the interest of scientific progress.

4. Beyond the Earth Station

Tsiolkovskiy was the first in the world to mention the idea of creating beyond the earth station which will serve as a flying observatory. In 1903, he wrote about the possibility of establishing a constant observatory, moving beyond the limits of atmosphere. In 1920 he described living conditions on a rocket - our planet's satellite, which is a universal space station and a laboratory for its study. Respiration, food, the establishment of artificial weight, clothing for hikes in vacuum space, necessary energy supply for the accomplishment of various works, communication with the earth, and other problems were carefully studied by Tsiolkovskiy. These problems were considered by him repeatedly.

Tsiolkovskiy paid considerable attention to the living conditions existing on the beyond the earth station and considered it as "the start of technical development in beyond the atmosphere regions". In many works, dedicated to space travels, we find ideas related to the "ether shelters" as Tsiolkovskiy called beyond the earth stations (Fig.27).

He indicates that such a station must be built in the space from parts delivered there from the earth by rockets. He specified the materials and design of these stations: it is a cylinder enclosed from sides by a half sphere divided on separate hermetic sections. Two-thirds of the area is finished with quartz glass. Tsiolkovskiy indicated how the temperature inside of the station can be regulated,

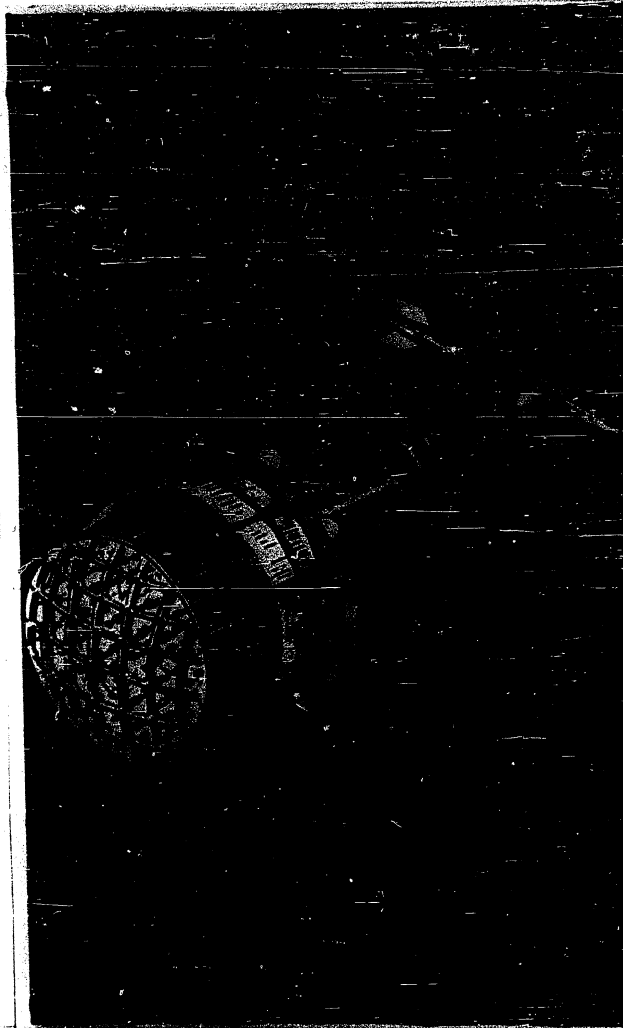


Fig.27. Outside of the Earth Station According to K.E.Tsiolkovskiy.

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the ways of energy supply (utilizing solar energy) gravity regulation by means of centrifugal force used for creating effects of artificial weight of required value.

"The adaption of plants for the purpose of purifying the air and producing food" has been considered by Tsiolkovskiy as one of the most important living conditions of the station.

He thoroughly analyzed the designs of hot houses (a long edifice with a half sphere connected to the base), the conditions which should be created there, air composition, atmospheric pressure, light, weight and other conditions.

To execute the various works outside of the station building, Tsiolkovskiy specified the use of special clothes and space helmets and indicated the conditions they must meet.

A big preparatory work should precede the establishment of the station.

Tsiolkovskiy assumed that the development of cosmic speed is required for converting the rocket into a satellite of the earth, and can be accomplished as a result of a gradual increase in altitude and in speed of motion. Beyond the earth's station - an earth satellite, becomes, thus, a necessary stage of the development.

The problem of a beyond-the-earth station, a scientific laboratory and an intermediate base for space ships, demands for its solution combining forces of various technological and scientific fields as: automatization and telemechanics, metallurgy, chemistry of radar and others.

Rocket technology will face a problem of designing rockets capable of taking off into space and of developing velocities sufficient for traveling along the circular orbit around the earth. In the future, the establishment of beyond-the-earth stations, traveling around the sun similarly to the ways of planets will be possible. Besides the people, the rocket must lift equipment required for the building of space stations. Because each kilogram, lifted beyond the limits of the atmosphere, requires the expenditure of fuel and energy, then it follows consequently that at least while the first stations are being built, the maximum

utilization of rocket parts as building material should be realized. These stations combined, form a living zone where also are situated laboratories, and different auxiliary accommodations. Fuel tanks are collected into a fuel storage zone from where the ships arriving at the stations will be refueled before the take-off into interplanetary flight. The station has the form of a cylinder. The artificial weight is created by rotating, and its value depends upon the diameter and circumferential speed. The inner surface is occupied by a hot house, inside is also situated a tunnel for the receiving and relieving rockets. Helium plants, which produce current for light, heating and other purposes and also an astronomical observatory with a telescope, are situated separately.

Because rotation would handicap observations and the operation of the helium plants, they are, therefore, connected to the station by means of pliable cables leading from the electrotransmitters and air conducting system attached to the observatory. To accomplish communication with the earth, and ships, traveling in the solar system and for the purpose of easing navigation in the universal space, and also in the close-to-the-station regions, there are corresponding radio establishments securing connections between the parts of the stations such as small rockets, which were rebuilt from the cabins and furnished with rocket motors(Fig.28).

The described project does not contain, of course, all the possible variations for a beyond-the-earth station. It is possible that at first the station will be of smaller dimensions and formed from a lesser number of rockets. At first, the station can be compiled without entrances into space from closely attached buildings, which later become connected by means of corridors. Gradually attaching to it all rockets arriving from the earth, as of the passenger type so automatically guided, the building becomes enlarged, storages appear and also the observatory and other spaces. The work is accomplished in protective suits, whereupon, the absence of weight and a possibility of developing high temperature by concentrating solar rays for helio-welding, facilitate the erection of buildings.

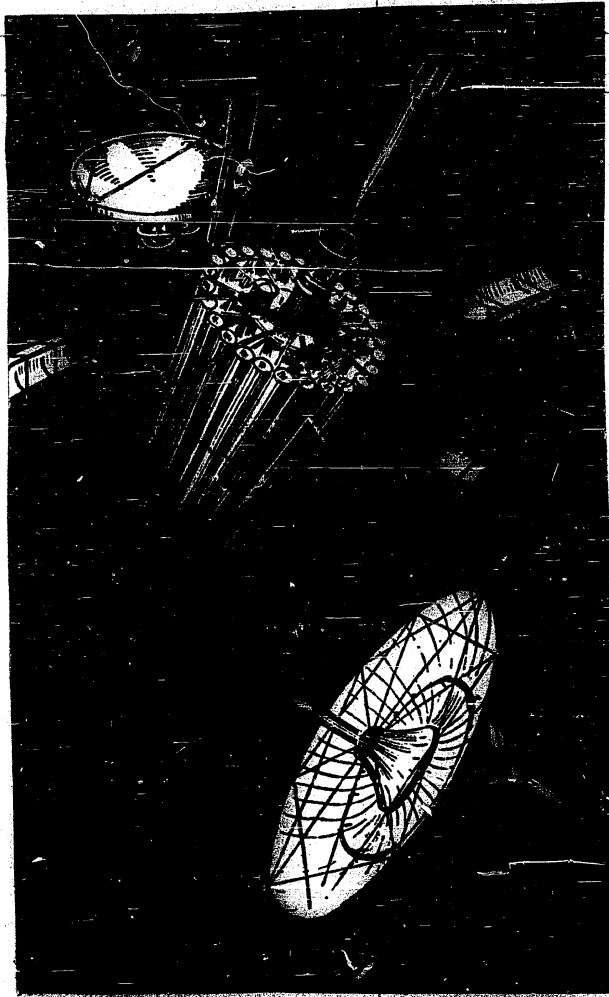


Fig.28. Projects of Outside of the Earth Stations.

A - A station compiled from rocket parts; 2 - Dwellings, laboratories, storerooms; 2 - Tunnel for launching and receiving rockets; 3 - Work shops; 4 - Hothouses; 5 - Observatory; 6 - Helium plants.
 B - A station compiled from the parts delivered from Earth; 1 - A reflector containing a helium plant;
 2 - Dwellings and auxiliary buildings (under the reflector); 3 - Air passage; 4 - Radio installation.

On the other hand, in the more remote future, when the progress in rocket techniques will permit the overcoming of difficulties connected with the achievement of cosmic speeds, the stations would be built from parts, especially delivered from the earth. One similar station of the English design, is shown in Fig.26. It consists of three parts, a solar mirror with an energetic plant, a living shelter beneath it and radio antennas attached to the end of a long girder and capable of changing its position in space. The exist is situated in a chamber with air vents, next to the living shelter at the other end of the girder which connects the antennas with the main parts of the station. An original station has been designed by G. Noordung. All chambers are situated in the rim of a wheel, excluding the helium plant.

Kondratyuk also investigated the problem of the beyond-the-earth station, an interplanetary base for rockets and for a beyond-the-atmosphere astronomical observatory. This base had been proposed to be converted into the satellite not of the earth, but of the moon. Because the moon has no atmosphere, the interplanetary "railroad station" will be beyond the action of air drag which could be considerable when air is greatly rarefied.

Kondratyuk assumed that the base must consist of four parts connected by light, aluminum girders. That will prevent the base from oscillating, making it more stable (Fig.29). Kondratyuk specified the possibility of establishing artificial ways by means of rotating and analyzed the problem of supply and communications with the earth.

A flight with landing on the moon, the closest to us heavenly body, represents a complicated problem for technical realization. In the future, the establishment of an outside-of-the-earth station, not of the artificial type, but a natural satellite is not excluded. Low weight - six times lower than that experienced on the earth, makes the moon a very convenient subject for this purpose and the absence of atmosphere creates especially suitable conditions for astronomical obser-

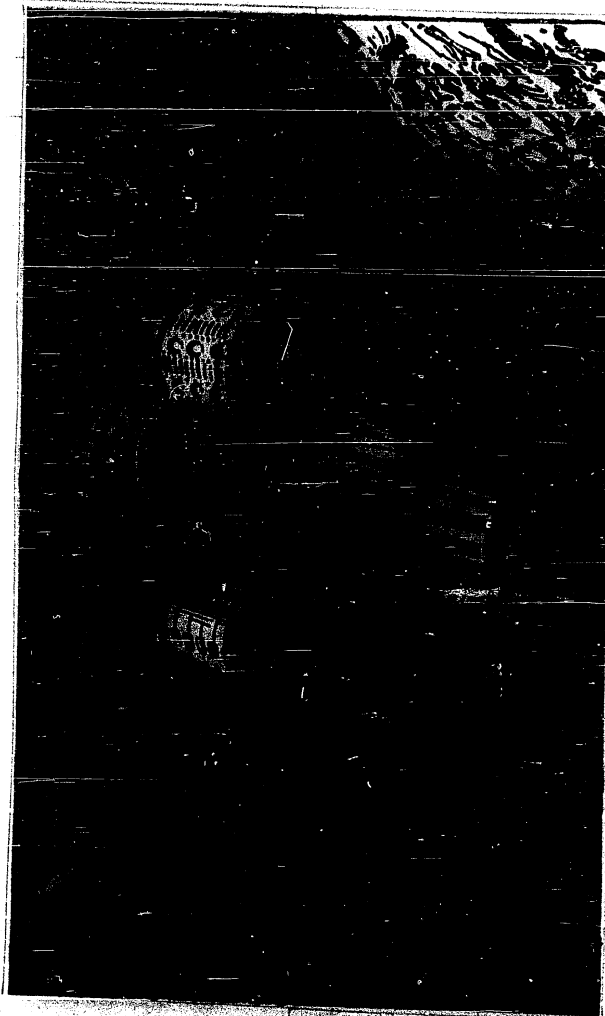


Fig.29. Outside of the Earth Station According to Yu.V.Kondratyuk.

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12 vations. Part of the shelters, for example fuel storages, can be placed under the
13 moon's surface; the others, like living quarters, observatory, helium electro-
14 stations, hothouses, radio plants, rocket-drome - on the surface of the moon.

15 Flights to asteroids, small planets, accumulated mainly between the orbits of
16 Mars and Jupiter, will make the organization of similar stations on their surface
17 possible.

18 The establishment of interplanetary stations will benefit the progress in all
19 science. Physics will study the phenomena occurring at very low and very high
20 temperatures easily produced in interspace. Astrophysics will conduct the study
21 of other planets. Thus the flight of automatic rockets equipped with research
22 and television instruments will play an important role.

23 Solar service, cosmic rays, processes occurring in the highest layers of at-
24 mosphere, this is an incomplete list of systematic observations under conditions
25 unobtainable on the earth.

26 Armed with modern astronomical techniques, the scientists will investigate
27 the cosmos.

28 It is quite possible that powerful telescopes will permit the cosmic astro-
29 nomes to observe such heavenly bodies that cannot be seen from the earth.

30 We shall receive new data on physical peculiarities of planets and character-
31 istics of interplanetary space.

32 Our conception of the world around us will be clearer and fuller.

33 Outside of the earth, where there is no atmosphere, the future technics will
34 learn how to use the unlimited solar energy for the benefit of mankind. The earth
35 receives only a small part of the solar energy radiated by the sun, approximately
36 one billionth part of it. Outside of the atmosphere there is an unlimited source
37 of energy.

38 The utilization of the energetic resources of the universal energy, prac-
39 tically unlimited solar energy, which he expected to harness, was considered by
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Tsiolkovskiy as a principle problem of the conquering of space.

According to Tsiolkovskiy, the problem following the flight beyond the limits of the atmosphere, after "the establishment of mobile space stations, similar to small satellite moons" will be the utilization of solar energy for traveling in the solar system and mastering it.

5. On the Road to a Cosmic Ship

Now it is still difficult to imagine the future space rocket ship in all the details.

An interplanetary flight will, evidently, require the accomplishment of a vast program of preparatory work on the earth and experimental climbings of passenger rockets as well as automatic pilotless mechanisms to high altitudes. Under the conditions existing on the earth, a study concerning the influence of overload, intensive ultraviolet rays, high and low temperatures, the living cycle of substances existing in a hermetically enclosed space upon the life activity of organisms and plants, is possible.

By lowering a high altitude rocket in exceptionally rarefied upper layer of atmosphere, similar to a free fall, it becomes possible to investigate the influence of imponderance. The observation of meteors in the vicinity of the earth will help establishing the region in which the encountering of them is less dangerous and to choose the orbit for the outside-of-the-earth station.

The realization of interplanetary travels poses a challenge to automatics and telematics for the development of automatic mechanisms, for guiding the rockets and for preserving the required orientation of the outside-of-the-earth station and its parts, for example hothouses and helium plants in position relative to the sun and telescopes in position relative to the observer. There will require such automatic instruments as for the control of air condensation systems and warming devices, in case of an accident, etc.

~~The constructors of devices must supply numerous instruments for cosmic~~

navigation, physical, astronomical and other investigations.

Metallurgy and chemistry must supply materials for rockets, motors and instruments capable of working under conditions of high and low altitudes and considerable overload. Radio-techniques must secure communication and telemechanical guidance for large distances, and also through the ionized layers of the atmosphere. It is possible that the first rockets which will investigate the universe, moon and planets, will be radio-guided rockets, and will transmit instrumental readings and television conveyances by radio.

Pilotless satellites of the earth, moon and pilotless moon rocket, will perhaps be the initial stages in the development of space travels. Then comes the turn of the outside-of-the-earth station, flight to the moon and to the planets.

The progress of the modern science and techniques is imposing. There are many questions to be answered, many problems to be solved, but even now, there is a possibility of taking off from the earth into the interplanetary space.

Tsiolkovskiy in his works gave much attention to aviation techniques. A rocket flight at high altitudes, in the stratosphere, in his opinion, must be considered as a preparation for a space travel. He often underlined the idea that "first comes the flight into the stratosphere, layer beyond the atmosphere - around the earth and further travels for longer distances".

In projects of a gradual development of rocket techniques, indicated by Tsiolkovskiy, he considered it necessary to study an aircraft with a rocket motor and a pressure cabin after the development of such a rocket motor was accomplished. Stratospheric flights of rocket airplanes and later their departure beyond the limits of the atmosphere, must serve as bases for beyond-the-atmosphere travels. Aviation, thus, becomes closely connected with the problem of interplanetary travels.

Of course, the utilization of atomic energy will be of a tremendous meaning for future interplanetary travels.

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Computations prove that a simple (not a stage) rocket, using the energy of chemical substances existing now or available in the future, is not capable of traveling in space. We saw that the highest jet speed which can be developed by it, is theoretically approximately equal to 4000 m/sec or even smaller.

One-stage rocket, powered by chemical energy, could fly in the space only if 96% of its weight is fuel and only 4% the rocket with the pay load, i.e. the fuel weight must exceed the weight of the construction 24 times. It is clear that such a rocket is difficult to realize. A stage rocket has better characteristics, but its initial weight is very high.

Atomic rocket motors will permit the realization of passenger travels to planets with, perhaps, landing on them.

Thus, to accomplish a flight to the moon with landing, the mass ration of the now existing rockets must be high. The atomic rocket, perhaps, will not exceed the magnitude reached until now.

The atomic energy opens before us vast possibilities.

The working principle of such a motor cannot now be foretold.

It seems that the simplest way is to force the products of atomic decomposition through the nozzle and to utilize the reaction force created by it.

High temperature is an unconquerable handicap in the way of immediate realization of atomic energy. It is 500,000 times higher than that created by the combustion of fuel. The rocket itself would inevitably evaporate. Besides that, a great expenditure of precious nuclear fuel would be required. The efficiency of the motor would be low.

The way of heat utilization, created by the decomposition of the atomic nucleus for heating some liquid, the vapor of which can be later ejected through the nozzle creating thrust, is more possible. Hydrogen can be used for this purpose. The amount of hydrogen or of any working liquid, must be considerably high, according to some calculations, equal to three-fourths of the rocket's weight, i.e. the

amount required by modern liquid fuel rockets. But the flow of velocity of hydrogen vapors heated by the heat of the atomic reactor, is several times greater than that developed by the combustion products. This is what secures the possibility of developing cosmic speeds.

That's true, that such use of atomic energy in a rocket motor produces tremendous temperatures. A possible way of protection is the employment of porous materials, possessing high heat conducting characteristics. This installation will have another important advantage. Along with hydrogen which is ejected, all products of radio-active decomposition will also be disposed of, taking into consideration their harmful influence, not only upon the motor but also upon the instruments and the crew.

However, the radio-active gases issued at the take-off present a danger for the people on the earth; therefore, the atomic motor, evidently, will be switched on only in the stratosphere and the take-off will be accomplished by means of boosters operating on non-atomic fuel. Atomic rocket, thus, will be a stage rocket, consisting of several stages, one of which uses a nuclear fuel, and the others, intended for take-off and landing, use chemical fuel (Fig.30).

Besides the utilization of heat, formed by the decomposition of atoms for heating a liquid or a gas, some other schemes of atomic motors are also available.

In the future, another possibility of hydrogen use will be introduced. When photo-elements and thermo-elements are highly efficient, helium electro-station will be capable of producing a current converting molecular hydrogen into an atomic one-component fuel intended for rocket ship motors. A reverse operation produces a high amount of heat forcing the hydrogen stream out at a speed equal approximately to 12 km/sec. Such an installation will develop high cosmic speeds in ships flying beyond the atmosphere, with departure from the outside-of-the-earth stations. If the technique of the wireless transmitting of energy for distance is mastered, the necessity of the helium plant in the ship becomes unnecessary; it can be replaced

by a receiver of energy from the outside of the earth station.

Now in the way of the development of the atomic motor, stands high temperature.

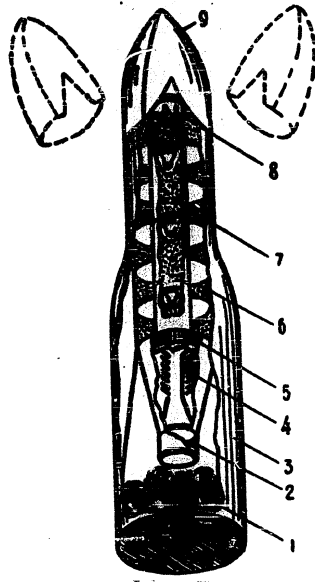


Fig. 30. Atomic Rocket.

1 - Chemical rocket booster; 2 - Pump fuel for the booster; 3 and 9 - Disposed tanks of the booster; 4 - Atomic reactor; 5 - Protective screen; 6 - Rejected tanks of the atomic rocket; 7 - Chemical three-stage rocket; 8 - Passenger cabin.

Atomic energy is radioactive radiations which are harmful to organisms.

The protective mediums against these radiations, which would protect the safety of the crew, and at the same time be light, must be developed.

Atomic energy is new motors with complex automatic mechanisms which must be built, experimented with and studied. All these problems will be without any doubt solved by the technical science of the future.

And with the appearance of the atomic rocket motors, a new page in the

history of rocket propulsion will be opened - interplanetary flights and the mastering of the universe. The clairvoyant words of Tsiolkovskiy will come true.

"First come flights in the stratosphere, later beyond the atmosphere. We have to toil more to conquer the stratosphere definitely and to come, finally, beyond its limits. It can be accomplished only here in the Soviet Union.

6. The Road to the Universe

...Armored curtains of illuminators in an interplanetary ship are drawn back. Before the eyes of travelers opens an imposing panorama of sky covered with stars. No one has ever seen it in this condition. Black, with clear unblinking stars, with an uneven disc of the sun, from which fire whirls are escaping. Here, faintly shining, is a scattering of stars of the Milky Way. And here, hanging in the sky is a big, bluish ball of the earth. It is enveloped in a cloudy smoke under which are faintly seen the outlines of the solid earth.

Behind are left, the first minutes during which the ship tried to overcome the force of gravity. Then, the force of overload heavily pressed the bodies to the backs of the chairs. It seems that a body is filled with lead, breathing is handicapped and so are movements and the ability to converse. At the moment when the engine ceased to work, the sensation of weight, as a reward for the experienced moments, completely disappears.

The sensation of imponderability is unusual; it appears that one is falling and cannot fall. All objects have lost their weight and the time of wonder began. Objects fell nowhere and only a slight push is sufficient to make them float around the cabin. Water cannot be spilled from a bottle turned upside-down. And if it is forced out, a gigantic drop of water, looking like a water ball, flies out of the bottle; being touched by any object, it becomes decomposed into several small water balls. There is no top or bottom. Flying in a bird-like manner, from one side to the other is possible. A small world without weight sensations, into which

the ship was transformed, is full of unexpectancies. But finally, even these things become familiar.

The walls are upholstered with leather and furnished with holders. All objects are fastened to certain places. Drinking containers are of a specially designed form, permitting comfortable drinking, avoiding the trick of imponderability. An electric stove is enclosed in a special container, permitting cooking without fear that cutlets will fly to the ceiling and soup will be spilled around the cabin.

But it is time for observations. Slowly, imperceptibly, the earth ball moves away. The ship flies now, as a small planet, under the way indicated by the law of heavenly mechanics. Here, where there is no atmosphere, the telescope opens new secrets of different worlds. Mountains and craters, familiar in pictures, are clearly seen. The trip is close to the end. In illuminators we can see the bulky, approaching body of the moon. We are all in our chairs again, the overload is experienced too, again the ship must fight the force of gravitation which indicated a fall catastrophe. The speed is reduced; these are the last moments of the travel and the passengers are on the moon.

The sluice opens and a man in a protective suit steps on the ground of the other world. Around the mountain chains, cliffs, ravines, landscapes of a desert, there is no water, air and there in the black sky, there shines a tremendous ball - distant and familiar earth. Some day it will be entered by people who will establish a station - a scientific little town where scientists could study the cosmos. Dwellings, observatory, storages, hothouses - all that is necessary for life on the moon, which will become the forepost on the road to the universe.

Interplanetary travels will be realized. With time, the large planets will also be accessible and perhaps, also visited as well as the asteroids.

An interplanetary flight is one of the most fascinating problems of the future. Even if it is theoretically solved, its practical realization demands a continuous work, mutual cooperation of the various technical fields, the utilization of the

modern developments of science. The complications in the production of space ships and in realization of travels cannot be underestimated. But we can be sure that this conquest will be realized. We are on our way to a cosmic ship and a day before the flight to the universal spaces.





CONCLUSIONS

"In the world, there is not a technique more complicated than rocket propulsion", said Tsiolkovskiy. The entire history of rocket development confirms the truthfulness of the words of Tsiolkovskiy. The way of modern rocket development has been long and difficult.

During the second world war, three new branches of technology were born: rocketry, atomic energy and radar techniques.

These accomplishments in scientific and technical progress are being employed by the aggressive circles of imperialistic countries for the purpose of destructive war. We must be ready to answer with a powerful blow to every aggressor who dares to attack the safety of our country. Rocketry along with other branches of our defense will serve the purpose of active defense of our country. Every weapon of aggression including rockets will be contrasted by corresponding mediums of defense. Remarkable successes in foremost Soviet scientific technical ideas, the care extended by the Party and government securing the growth of the power in our socialist state, together with other peace-loving countries is the guarantee to that.

We assume that the most important problem is the utilization of scientific and technical developments for the purpose of peaceful, creative progress. That is why we pay great attention to rocket propulsion as a new powerful weapon of natural

science.

Rocket propulsion has wide, open horizons.

Without any doubt, our native rocket techniques with its glamorous traditions of Konstantinov, Kibalchich, Tsiolkovskiy, multiplied by the Soviet engineers and scientists, will always be the best in the world.

The achievements in the field of rocketry are directed to the purpose of peace. The intention of a rocket is, first of all, the increasing power of creative mankind in his victory over time and space. In our country, it has served and will serve to the business of peace protection, scientific development and national economic progress of our great country".

"Only my great proletariat country, only my Fatherland can maintain and bring up people who fearlessly lead the new mankind toward happiness and joy"(Tsiolkovskiy).

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0 The book describes the theory of rocket motion in vacuum and in air,
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4 and high-altitude flights and for space travels.

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8 Communications", "Powder Rocket Motor", "Rocket Launching Devices", "Rocket", are
10 articles contained in the "Big Soviet Encyclopedia", latest printing.
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